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7. Author(s)
OFFICE OF SOLID WASTE

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401 M STREET, SW
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This document, ~~which is~~ presented in four volumes, provides guidance to ~~the~~ owner or operator of hazardous waste management facilities as to the conduct of the second phase of the RCRA Corrective Action Program, the RCRA Facility Investigation. This document provides ~~the~~ owner or operator with guidance on conducting a RFI, based on release determinations made by the regulatory agency. The owner or operator of a facility is notified, through an enforcement order or permit conditions, of those unit(s) and releases (known or suspected) which must be further investigated. Media of concern include: soil, ground water, subsruface gas, air, and surface water. Volume I presents the procedures and rationale that should be used to develop a work plan for conducting the investigation, a general strategy for release investigations, ~~several~~ other aspects of the investigation and, the means by which the data collected during the RFI will be intrepreted by the regulatory agency. Volumes II and III describe media-specific methods for conducting a RFI. Volume IV presents ~~a number of~~ case study illustrations ~~on~~ various aspects of the RFI process.

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RCRA FACILITY INVESTIGATION (RFI) GUIDANCE

VOLUME I OF IV

DEVELOPMENT OF AN RFI WORK PLAN AND GENERAL CONSIDERATIONS FOR RCRA FACILITY INVESTIGATIONS

EPA 530/SW-87-001A

DRAFT

JULY 1987 *

WASTE MANAGEMENT DIVISION
OFFICE OF SOLID WASTE
U.S. ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

On November 8, 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to RCRA. Among the most significant provisions of HSWA are §3004(u), which requires corrective action for releases of hazardous waste or constituents from solid waste management units at hazardous waste treatment, storage and disposal facilities seeking final RCRA permits; and §3004(v), which compels corrective action for releases that have migrated beyond the facility property boundary. EPA will be promulgating rules to implement the corrective action provisions of HSWA, including requirements for release investigations and corrective measures.

This document, which is presented in four volumes, provides guidance to the owner or operator of hazardous waste management facilities as to the conduct of the second phase of the RCRA Corrective Action Program, the RCRA Facility Investigation (RFI). Instruction is provided for the development and performance of an investigation based on determinations made by the regulatory agency as expressed in the schedule of a permit or in an enforcement order issued under HSWA§3008(h). The purpose of the RFI is to obtain information to fully characterize the nature and extent of releases of hazardous waste or constituents. This information will be used to determine whether interim corrective measures or a Corrective Measures Study will be necessary.

DISCLAIMER

This Draft Report was prepared for the U.S. Environmental Protection Agency by the NUS Corporation, Waste Management Services Group, Gaithersburg, MD 20878, in fulfillment of Contract No. 68-01-7310, Work Assignment No. 5, and is based on previous work performed by Alliance Technologies, Inc., under Contract No. 68-01-6871. The opinions, findings, and conclusions expressed herein are those of the authors and not necessarily those of the U.S. Environmental Protection Agency or the cooperating agencies. Mention of company or product names is not to be considered an endorsement by the U.S. Environmental Protection Agency.

This document is intended to assist Regional and State personnel in exercising the discretion conferred by regulation in developing requirements for the conduct of RCRA Facility Investigations (RFIs) pursuant to 40 CFR 264. Conformance with this guidance is expected to result in the development of RFIs that meet the regulatory standard of adequately detecting and characterizing the nature and extent of releases. However, EPA will not necessarily limit acceptable RFIs to those that comport with the guidance set forth herein. This document is not a regulation (i.e., it does not establish a standard of conduct which has the force of law) and should not be used as such. Regional and State personnel must exercise their discretion in using this guidance document as well as other relevant information in determining whether an RFI meets the regulatory standard.

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Guidance was also provided by the EPA RFI Work Group, including:

George Furst, Region
Andrew Bellina, Region II
William Smith, Region II
Jack Potosnak, Region III
Douglas McCurry, Region IV
Francine Norling, Region V
Lydia Boada Clista, Region VI
Karen Flournoy, Region VII
Larry Wapensky, Region VIII
Julia Bussey, Region IX
Melanie Field, Region IX
Jim Breitlow, Region IX
Paul Day, Region X
David Adler, OPPE
Joanne Bahura, WMD

Janette Hansen, PSPD
Lisa Feldt, HSCD
Stephen Botts, OECM
Chris DeRosa, OHEA
James Durham, OAQPS
Mark Guilbertson, OWPE
Nancy Hutzel, OGC
Steve Golian, OERR
Dave Eberly, PSPD
Jackie Krieger, OPPI
Lisa Lefferts, PSPD
Florence Richardson, CAD
Reva Rubenstein, CAD
Steve Sisk, NEIC

This document was prepared by the NUS Corporation, Tetra Tech, Inc., and Labat Anderson, Inc., and was based on previous work performed by Alliance Technologies, Inc. The principal authors included:

Todd Kimmell, NUS
Kurt Sichelstiel, NUS
William Murray, NUS
Ron Stoner, NUS
John George, NUS
Ray Dever, NUS
Dave Navecky, NUS

Tom Grieb, Tetra Tech
Kay Johnson, Tetra Tech
Bill Mills, Tetra Tech
Nick Pangaro, Alliance
Linda Marler, Alliance
Andrea Mysliki, Labat Anderson

RCRA FACILITY INVESTIATION (RFI) GUIDANCE

VOLUME I

DEVELOPMENT OF AN RFI WORK PLAN AND GENERAL CONSIDERATIONS FOR RCRA FACILITY INVESTIGATIONS

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LIST OF ACRONYMS

AA - Atomic Absorption
AI - Soil Adsorption Isotherm Test
ASCS - Agricultural Stabilization and Conservation Service
ASTM - American Society for Testing and Materials
BCF - Bioconcentration Factor
BOD - Biological Oxygen Demand
CAG - EPA Carcinogen Assessment Group
CPF - Carcinogen Potency Factor
CBI - Confidential Business Information
CEC - Cation Exchange Capacity
CERCLA - Comprehensive Environmental Response, Compensation, and Lability Act
CFR - Code of Federal Regulations
CIR - Color Infrared
CM - Corrective Measures
CMI - Corrective Measures Implementation
CMS - Corrective Measures Study
COD - Chemical Oxygen Demand
COLIWASA - Composite Liquid Waste Sampler
DNPH - Dinitrophenyl Hydrazine
DO - Dissolved Oxygen
DOT - Department of Transportation
ECD - Electron Capture Detector
EM - Electromagnetic
EP - Extraction Procedure
EPA - Environmental Protection Agency
FEMA - Federal Emergency Management Agency
FID - Flame Ionization Detector
Foc - Fraction organic carbon in soil
FWS - U.S. Fish and Wildlife Service
GC - Gas Chromatography
GC/MS - Gas Chromatography/Mass Spectroscopy
GPR - Ground Penetrating Radar
HEA - Health and Environmental Assessment
HEEP - Health and Environmental Effects Profile
HPLC - High Pressure Liquid Chromatography
HSWA - Hazardous and Solid Waste Amendments (to RCRA)
HWM - Hazardous Waste Management
ICP - Inductively Coupled (Argon) Plasma
ID - Infrared Detector
Kd - Soil/Water Partition Coefficient
Koc - Organic Carbon Absorption Coefficient
Kow - Octanol/Water Partition Coefficient
LEL - Lower Explosive Limit
MCL - Maximum Contaminant Level
MM5 - Modified Method 5
MS/MS - Mass Spectroscopy/Mass Spectroscopy
NFIP - National Flood Insurance Program
NIOSH - National Institute for Occupational Safety and Health
NPDES - National Pollutant Discharge Elimination System
OSHA - Occupational Safety and Health Administration

LIST OF ACRONYMS (Continued)

OVA - Organic Vapor Analyzer
PID - Photo Ionization Detector
pKa - Acid Dissociation Constant
ppb - parts per billion
ppm - parts per million
PUF - Polyurethane Foam
PVC - Polyvinyl Chloride
QA/QC - Quality Assurance/Quality Control
RCRA - Resource Conservation and Recovery Act
RFA - RCRA Facility Assessment
RfD - Reference Dose
RFI - RCRA Facility Investigation
RMCL - Recommended Maximum Contaminant Level
RSD - Risk Specific Dose
SASS - Source Assessment Sampling System
SCBA - Self Contained Breathing Apparatus
SCS - Soil Conservation Service
SOP - Standard Operating Procedure
SWMU - Solid Waste Management Unit
TCLP - Toxicity Characteristic Leaching Procedure
TEGD - Technical Enforcement Guidance Document (EPA, 1986)
TOC - Total Organic Carbon
TOT - Time of travel
TOX - Total Organic Halogen
USGS - United States Geologic Survey
USLE - Universal Soil Loss Equation
UV - Ultraviolet
VOST - Volatile Organic Sampling Train
VSP - Verticle Seismic Profiling
WQC - Water Quality Criteria

SUMMARY

The Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) were enacted into law on November 8, 1984. One of the major provisions (Section 3004(u)) of these amendments requires corrective action for releases of hazardous waste or constituents from solid waste management units (SWMU's) at hazardous waste treatment, storage, or disposal facilities. Under this provision, any facility applying for a RCRA hazardous waste management facility permit will be subject to a RCRA Facility Assessment (RFA). The RFA is conducted by the regulatory agency to whom the permit application has been submitted, and is designed to identify SWMU's which are, or are suspected to be, the source of a release to the environment. If any such units are identified, the owner or operator of the facility will be directed to perform a RCRA Facility Investigation (RFI) to obtain information on the nature and extent of the release so that the need for interim corrective measures or a Corrective Measures Study can be determined. Information collected during the RFI can also be used by the owner or operator to aid in formulating and implementing appropriate corrective measures. Such corrective measures may range from stopping the release through the application of a source control technique to a full-scale cleanup of the affected area.

This document provides the owner or operator with guidance on conducting a RCRA Facility Investigation, based on release determinations made by the regulatory agency (generally resulting from the RFA). The owner or operator of a facility is notified, through an enforcement order or permit conditions, of those unit(s) and releases (known or suspected) which must be further investigated. Media of concern include:

- Soil;
- Ground Water;
- Subsurface Gas;
- Air; and

- Surface Water.

This guidance is divided into fifteen sections presented in four volumes. Volume I presents the procedures and rationale that should be used to develop a work plan for conducting the investigation, a general strategy for release investigations, several other aspects of the investigation and, the means by which the data collected during the RFI will be interpreted by the regulatory agency. Volumes II and III describe media-specific methods for conducting a RFI. Volume II describes investigations of subsurface releases to soil and ground water and releases via subsurface gas. Volume III addresses releases to air and surface water. Volume IV presents a number of case study illustrations on various aspects of the RFI process. Cross references exist between the media-specific sections because inter-media transfer of contamination can occur frequently.

Prior to conducting the investigation, the owner or operator will in most cases be directed to to submit a written plan (the RFI Work Plan) that should propose, in detail, the manner in which the investigation will be conducted. Specific components of this plan are defined in Volume I of this guidance.

In planning the investigation, the owner or operator should consider a logical progression of tasks that will be followed in investigating the release. Generally, these tasks will consist of:

- Gathering information on the source of the release to the environment (e.g., gathering information on the unit and the waste in the unit);

- Gathering physical information on the environment surrounding the unit that will affect the migration and fate of the release (e.g., ground-water flow direction, average windspeeds, soil types); and

- Using this information along with any existing monitoring information, to develop a conceptual model of the release, and plan and conduct a monitoring program to define the nature rate and extent of the release.

The owner or operator should use existing sources of information when these sources can supply data of the quality and type needed. Information on waste constituents, for instance, may be available from operational records kept at the facility. In other instances, the owner or operator may propose a waste sampling and analysis effort to characterize the waste in the unit of concern, thereby producing new data on the waste. In either case, the owner or operator should ensure that the data is of the quality necessary to adequately define the release because such data will be used in determining the need for corrective measures.

Characterizing the release source and the environmental setting of the release will allow the owner or operator to design a monitoring program which will lead to adequate characterization of the release. This effort may be conducted in phases, with each monitoring phase building on the findings and conclusions of the previous phase. For example, in those cases where the regulatory agency has identified a suspected release, the first phase of the monitoring program might be directed toward release verification. The level of effort required in an initial monitoring phase will thus be dictated by the level of knowledge on the release. Some hypothetical examples of this approach are given below.

- A facility contains both active and inactive landfills. All active landfills at the facility are regulated for ground-water releases under 40 CFR Part 264, Subpart F; however, an inactive unit was identified by the regulatory agency as being the source of a release to ground water. The waste in the unit was identified by the owner or operator as being supplied solely by a single, well-characterized process.

  Hydrogeologic information, such as identification of the uppermost aquifer and ground-water flow direction and rate, were defined in the RCRA permit application for the active units required for compliance with Subpart B of 40 CFR Part 270. Environmental characterization data relevant to the inactive landfill, such as flow direction and hydraulic gradient, was derived from monitoring wells already installed to comply with the monitoring requirements of 40 CFR Part 264, Subpart F.

  In this case, the owner or operator was able to use existing information to characterize both the environmental setting and the source of the release and conduct a limited sampling program, starting with wells near the inactive unit, to define the release. After installation and sampling of these initial wells, the owner or operator determined the need for further well installation and sampling. In this case, the level of effort required to characterize the release, especially in characterizing the contaminant source and environmental setting, was minimal due to the detailed information already available.

- In another case, the owner or operator of a commercial facility with an inactive surface impoundment that had received waste from several generators was directed to conduct an investigation of a suspected release to a nearby stream. The suspicion of a release was based on several fishkills noted in the stream during periods of heavy rains and reported observations of impoundment overflow during these periods. The owner or operator's knowledge of the impoundment's contents was limited due to the varying wastes managed, and a survey of drainage patterns around the impoundment had not been performed. Also, monitoring of the receiving stream itself had not been conducted at the time of the notification.

  In this case, an extensive level of effort was required to characterize the release. Since the waste could not be readily characterized by direct sampling due to its varying nature over time, the owner or operator proposed to forego a waste characterization effort and conduct monitoring of the receiving stream for the constituents of concern. The owner or operator conducted a survey of drainage patterns around the site, developed a conceptual model of the release, and established a network of monitoring stations. Initial sampling was conducted in drains and swales around the unit, with subsequent monitoring taking place in drainage ditches and eventually the stream itself, with the design of each sampling effort based on knowledge gained from the previous effort. In addition, since contamination of the surface water column occurred only during periods of heavy rains, sampling of the water column was conducted during such periods. The owner or operator also determined, through analysis of samples collected in the initial phases, that the waste constituents being released were highly water soluble and not likely to contaminate bottom sediments. In addition, these constituents had a low potential to bioaccumulate. Stream sampling, therefore, was limited to water column samples; bottom sediment and biota sampling were not performed.

- During a visual site inspection conducted by the regulatory agency as part of the RCRA Facility Assessment, evidence was found that ten drums, that were placed in an unrestricted storage area were releasing their contents to soils surrounding the area. Evidence observed by the investigative team included discolored soils and stressed vegetation. The regulatory agency issued a compliance order requiring the owner or operator to immediately remove the drums (as an interim corrective measure) and conduct an investigation of the nature and extent of the contamination. The owner or operator complied with the order for removal and conducted sampling to characterize the waste in the drums. After identifying the constituents of the waste, the owner or operator proposed to perform a phased effort to characterize the release, starting with a screening of the area using an organic vapor analyzer (OVA) followed by the collection of samples in the immediate vicinity of the drum storage area, with subsequent sampling taking place at progressively further distances from the area. After collection of three rounds of sampling, sufficient data had been gathered to adequately define the extent of the release.

The above three examples illustrate general concepts that may vary on a site-specific basis.

The owner or operator should understand that the regulatory agency has a responsibility to ensure the protection of human health and the environment, and hence, a significant oversight role. Accordingly, the regulatory agency will generally wish to oversee all RFI-related operations, including field and sampling operations. Regulatory agency oversight of RFI field work is very important for ensuring a quality study. In planning and conducting the RFI, therefore, the owner or operator is encouraged to interact closely with the regulatory agency to assure that the data supplied during the investigation and, thus, the interpretation of the data, will be acceptable. The compliance order or permit conditions requiring the investigation will specify a schedule for conducting the investigation, including the submission of data. The owner or operator should keep the regulatory agency advised of the progress of the investigation, including any delays, changes, or deletions.

These volumes present guidance specific to the RFI and the RFI process. General subject areas which are common to many types of investigations (e.g., quality assurance and control, sampling, analytical methods, health and safety procedures), but are nevertheless important to the RFI, are addressed in a summary fashion and points important to consider during the RFI are brought out and references to additional information are provided.

This RFI Guidance is tailored to the structure and goals of the RCRA corrective action program. The RFI process described in this document parallels (in a gross sense) the Remedial Investigation (RI) and removal components of guidance issued under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The RFI Guidance has been developed to address releases from operating as well as inactive and closing units. When such releases have been adequately characterized, the next step in the RCRA corrective action process can be initiated (i.e., identification of the need for and implementation of corrective measures).

SECTION 1

OVERVIEW OF THE RCRA CORRECTIVE ACTION PROGRAM

1.1 Introduction

The primary objective of the RCRA corrective action program is to clean up releases of hazardous waste or hazardous constituents from solid waste management units at hazardous waste treatment, storage, or disposal facilities. The program was mandated by the 1984 Hazardous and Solid Waste Amendments (HSWA), which provided EPA with broad authorities for assuring corrective action at facilities subject to RCRA. These authorities are:

- Section 3004(u) - Corrective Action for Continuing Releases

  Section 3004(u) of HSWA requires that permits issued after the date of enactment of HSWA (November 8, 1984) require corrective action for releases of hazardous waste or constituents from any solid waste management unit (SWMU) at any hazardous waste treatment, storage, or disposal facility seeking a permit, regardless of the time at which waste was placed in the unit.

- Section 3008(h) - Interim Status Corrective Action Orders

  Section 3008(h) of HSWA authorizes EPA to issue orders requiring corrective action or to take other appropriate response measures to protect human health and the environment based on any information that there is or has been a release of hazardous waste into the environment from a facility authorized to operate under Section 3005(e).

- Section 3004(v) - Corrective Action Beyond the Facility Boundary

  Section 3004(v) authorizes EPA to require that corrective action be taken by the facility owner or operator beyond the facility property boundary where necessary to protect human health and the environment, unless the owner or operator demonstrates that permission to undertake such action was denied.

Section 3005(c)(3) of HSWA (commonly known as the "Omnibus" provision) gives EPA authority to add any conditions to RCRA permits deemed necessary to protect human health and the environment.

In addition, Section 3004(n) of HSWA directs EPA to set standards for the control and monitoring of air emissions at hazardous waste treatment storage and disposal facilities as necessary to protect human health and the environment. These standards are being developed at this time and will form the overall basis for regulating air emissions at these facilities. These standards may be used by EPA in evaluating corrective actions associated with air releases at solid waste management units. However, until these standards are sufficiently developed, EPA will use this RFI Guidance to address air releases that may require corrective actions.

Section 3004(n) has been codified as 40 CFR §264.101. A companion to EPA's July 15, 1985 (see 50 FR 28702) codification rule will specify additional information and data requirements for owners or operators on solid waste management units to support the conduct of RCRA Facility Assessments by the regulatory agency; this rule is expected to be promulgated by the summer of 1987. These authorities broaden the scope of the RCRA corrective action program from detecting and correcting releases to the uppermost aquifer from regulated units, to cleaning up continuing releases to any media resulting from other waste management units and practices at RCRA facilities. Prior to passage of HSWA, EPA exercised its authority under Section 3004 to require corrective action for releases of hazardous constituents to ground water from only certain land-based waste management units; 40 CFR Part 264, Subpart F contains requirements for corrective action at these "regulated units." Regulated units include surface impoundments, landfills, waste piles, and land treatment units that received hazardous waste on or after July 26, 1982. HSWA extended RCRA authority to correct releases to all media from all solid waste management units at RCRA facilities, and encourages the use of other authorities, as needed or appropriate, to help achieve corrective action objectives at these facilities.

The HSWA corrective action provisions focus on investigating releases from solid waste management units (SWMU's). A SWMU is any discernible unit at which solid or hazardous wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous wastes. Such units include any area at a facility at which hazardous wastes or hazardous constituents have been routinely and systematically released. A SWMU does not include accidental spills from production areas and units in which wastes have not been managed (e.g., product storage areas).

The RFI Guidance addresses investigations of all releases from SWMUs to all media, including soil, ground water, subsurface gas, air, and surface water. Ground water releases from regulated units will continue to be regulated under 40 CFR Part 264, Subpart F.

1.2 Overall RCRA Corrective Action Process

The RCRA Corrective Action Process consists primarily of four steps: the RCRA Facility Assessment (RFA), the RCRA Facility Investigation (RFI), the Corrective Measures Study (CMS), and Corrective Measures Implementation (CMI). A summary of the overall corrective action process for identifying, characterizing, and correcting releases is presented in Figure 1-1. The overall corrective action process is discussed below.

RCRA Facility Assessment (RFA)

Release determinations for all environmental media (i.e., soil, ground water, subsurface gas, air, or surface water) will be made by the regulatory agency primarily through the RCRA Facility Assessment (RFA) process. The regulatory agency will perform the RFA for each facility seeking a RCRA permit to determine if there are continuing releases of concern. The major objectives of the RFA are to:

- Identify solid waste management units (SWMUs) and collect existing information on contaminant releases; and

REGULATORY AGENCY performs RCRA Facility Assessment (RFA) to:

- Identify solid waste management units (SWMUs) and collect existing information on contaminant releases.
- Identify releases or suspected releases needing further investigation

↓

REGULATORY AGENCY specifies permit conditions or issues enforcement order to facility owner or operator to:

- Perform investigations on releases of concern; and/or
- Implement interim corrective measures.

↓

OWNER OR OPERATOR performs RCRA Facility Investigation (RFI) to verify the release(s), if necessary, and to characterize the nature, extent and rate of migration for releases of concern. Owner or operator contacts the regulatory agency immediately if interim corrective measures seem warranted.

↓

REGULATORY AGENCY conducts health and environmental assessment based on results of RFI and determines the need for interim corrective measures, and/or a Corrective Measures Study.

↓

OWNER OR OPERATOR conducts Corrective Measures Study (CMS) as directed by regulatory agency and proposes appropriate corrective measures when required by regulatory agency.

↓

REGULATORY AGENCY evaluates Corrective Measures Study and specifies appropriate corrective measures.

↓

OWNER OR OPERATOR performs the corrective measures implementation (CMI). This includes designing, constructing, operating, maintaining and monitoring the corrective measures.

Figure 1-1: RCRA Corrective Action Process. Note that although certain aspects of the corrective action process are the responsibility of either the regulatory agency or the owner or operator, close coordination between the regulatory agency and the owner or operator is essential.

- Identify releases or suspected releases needing further investigation.

The RFA begins with a preliminary but fairly comprehensive review of pertinent existing information on the facility. If necessary, the review is followed by a visual site inspection to verify information obtained in the preliminary review and to gather information needed to develop a sampling plan. A sampling visit is subsequently performed, if necessary, to obtain appropriate samples for making release determinations.

The findings of the RFA will result in one or more of the following actions:

- No further action under the RCRA corrective action program is required at that time, since no evidence of release(s) or of suspected release(s) was identified;

- A RFI by the facility owner or operator is required where the information collected indicates a release(s) or suspected release(s) that warrants further investigation;

- Interim corrective measures by the owner or operator are required where the regulatory agency believes that expedited action should be taken to protect human health or the environment; and

- In cases where problems associated with permitted releases are found, the regulatory agency will refer such releases to the appropriate permitting authorities.

Guidance for conducting the RFA is presented in the following reference:

U.S. EPA. October, 1986. RCRA Facility Assessment Guidance. NTIS PB 87-107769. Office of Solid Waste. Washington, D.C. 20460.

RCRA Facility Investigation (RFI)

If the regulatory agency determines that a RFI is necessary, this investigation will be required of the owner or operator either under a permit schedule of compliance or under an enforcement order. The regulatory agency will apply the appropriate regulatory authority and develop specific conditions in permits or enforcement orders. These conditions will generally be based on results of the RFA and will identify specific units or releases needing further investigation. Such permits or orders may be accompanied by a supporting fact sheet. The RFI can range widely from a small specific activity to a complex multi-media study. In any case, through these conditions, the regulatory agency will direct the owner or operator to investigate releases of a concern. The investigation may initially involve verification of suspected releases. If confirmed, further characterization of such releases will be necessary. This characterization includes identification of the type and concentration of hazardous waste or hazardous constituents released, the rate and direction at which the releases are migrating, and the distance over which releases have migrated. Inter-media transfer of releases (e.g., volatilization of hazardous constituents from contaminated soils to the air medium) should also be addressed during the RFI, as appropriate.

The RFI step also includes interpretation by the regulatory agency of release charactization data against established health and environmental criteria to determine whether a Corrective Measures Study is necessary. This evaluation is crucial to the corrective action process. The regulatory agency will ensure that data and information collected during the RFI adequately describe the release, and can be used to make decisions regarding the need for a Corrective Measures Study with a high degree of confidence.

Identifying and implementing interim corrective measures may also be conducted during the RFI. If, in the process of conducting the investigation, a condition is identified that indicates that adverse exposure to hazardous constituents is presently occurring or is imminent, interim corrective measures may be needed. Both the owner or operator and the regulatory agency have a continuing responsibility to identify and respond to emergency situations and to define priority situations that warrant interim corrective measures. The need for consideration of interim corrective measures, if identified by the owner or operator, should be communicated to the regulatory agency at the earliest possible time. As indicated earlier, the need for interacting closely with the regulatory agency is very important, not only for situations discussed above, but also to assure the adequacy of the data collected during the RFI and the appropriate interpretation of those data.

Corrective Measures Study (CMS)

If the potential need for corrective measures is identified during the RFI process, the owner or operator is then responsible for performing a Corrective Measures Study (CMS). During this step of the corrective action process, the owner or operator will identify, and recommend as appropriate, specific corrective measures that will correct the release.

Information generated during the RFI will be used not only to determine the potential need for corrective measures, but also to aid in the selection and implementation of these measures. While conducting the RFI, the owner or operator is encouraged to collect data (e.g., engineering data such as soil compaction properties or aquifer pumping tests), which may be needed to select and implement corrective measures. Selection and implementation of corrective measures will be addressed in separate guidance to be developed by EPA. In the interim, guidance for corrective measures selection and implementation is provided in the following references:

U.S. EPA. September, 1986. Data Requirements for Remedial Action Technology Selection. Final Report. NTIS PB87-110813. Office of Emergency and Remedial Response and Office of Research and Development. Washington, D.C. 20460.

U.S. EPA. October, 1985. Handbook of Remedial Action at Waste Disposal Sites. EPA/625-6-85-006. Office of Emergency and Remedial Response. Washington, D.C. 20460.

U.S. EPA. June, 1985. Guidance on Feasibility Studies Under CERCLA. NTIS PB85-238590. Office of Emergency and Remedial Response. Washington, D.C.

U.S. EPA. June, 1987. RCRA Corrective Action Interim Measures. Interim Final. OSWER Directive No. 9902.4. Office of Waste Programs Enforcement. Washington, D.C. 20460.

Corrective Measures Implementation (CMI)

Corrective measures implementation includes designing, constructing, operating, maintaining and monitoring selected corrective measures. As indicated above, selection and implementation of corrective measures will be addressed in separate guidance to be developed by EPA.

1.3 Purpose of the RCRA Facility Investigation (RFI) Guidance

This document provides guidance to both the facility owner or operator and regulatory agency personnel on conducting a RFI to characterize the nature, extent, and rate of migration of releases to soils, ground water, subsurface gas, air, and surface water from SWMUs (hereafter also referred to as units). It also provides guidance on the interpretation of results to determine if interim corrective measures and/or a Corrective Measures Study may be necessary.

This RFI Guidance is not intended to describe all activities that may be undertaken during the RFI. For example, consideration of community relations and development of a community relations plan may be advisable on a case-specific basis. This and other items that may be undertaken during the RFI are outlined in the following document:

U.S. EPA. November 1986. RCRA Corrective Action Plan. Interim Final. OSWER Directive No. 9902.4 Office of Solid Waste and Emergency Response. Washington, D.C. 20460.

This document provides as much procedural specificity as possible to clearly define the owner or operator's responsibilities in the RFI. Each situation, however, is likely to be unique. Site-specific conditions, including the amount and quality of information available at the start of the RFI process, the existence of or potential for actual exposure, and the nature and extent of the release call for a flexible approach to the release investigation. This guidance is written in this context. However, some situations may be so complicated and unique that further technical guidance may be necessary. If this is the case, the owner or operator should contact the responsible regulatory agency for assistance. If necessary, the responsible regulatory agency will contact EPA headquarters.

1.4 Organization of this Document

This guidance is organized into four volumes containing fifteen sections and five appendices. Volume I contains eight sections: Section 2 provides direction for preparation of the RFI Work Plan and procedures for submitting this Plan to the regulatory agency for review. Section 3 provides guidance on the general strategy to be employed in performing release investigations. Sections 4, 5, and 6 discuss Quality Assurance/Quality Control (QA/QC), Data Management and Presentation, and Health and Safety Procedures, respectively. Section 7 discusses how information from source (waste and unit) characterization can be used in the RFI process. Section 8 presents guidance on the interpretation of data collected during the RFI process, using health and environmental criteria. Guidance for situations that may require the application of interim corrective measures is also provided in Section 8.

Volumes II and III provide detailed technical guidance on how to perform media-specific investigations. Volume II presents Sections 9, 10 and 11, which discuss the soil, ground water, and subsurface gas media, respectively. Volume III presents Sections 12 and 13, which discuss the air and surface water media, respectively. Representative case study illustrations of various investigative approaches and techniques described in Volumes I through III are presented in Sections 14 and 15 of Volume IV.

1.5 Reference Information

This document provides guidance on characterizing known releases and on verification of suspected releases. Applicable field methods (e.g., sampling techniques) and equipment are described or referenced, as appropriate. This document uses, to the extent possible, existing guidances and information developed in various EPA programs (e.g., Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Air Quality Planning and Standards, and Office of Water), as well as State material to assist in performing release characterizations for the various environmental media. As such, many references are provided which refer the owner or operator to more complete or detailed information. Where available, identification or ordering numbers have been supplied with these citations. The following describes these identification numbers and provides information on how these documents may be obtained.

NTIS: NTIS stand for the National Technical Information Service. NTIS documents may be obtained by calling (703) 487-4650 or by writing to NTIS at the following address:

NTIS
U.S. Department of Commerce
Springfield, VA 22161

EPA: Environmental Protection Agency (EPA) Reports are available through EPA's headquarters or regional libraries, or through writing to EPA at the following address:

U.S. EPA
Public Information Center
401 M. Street, S.W.
Washington, D.C. 20460

Many EPA reports are also available through NTIS. NTIS should be contacted for availability information. The indicated EPA office may also be contacted for information by writing the the above address.

OSWER: OSWER stands for EPA's Office of Solid Waste and Emergency Response. Documents identified by an OSWER Directive Number can be obtained by calling EPA's RCRA/Superfund Hotline for availability information, at (800) 424-9346 (toll-free) or (202) 382-3000.

GPO: GPO stands for the U.S. Government Printing Office. Documents available through GPO may be obtained by calling GPO at (202) 275-3648.

SECTION 2

THE RFI WORK PLAN

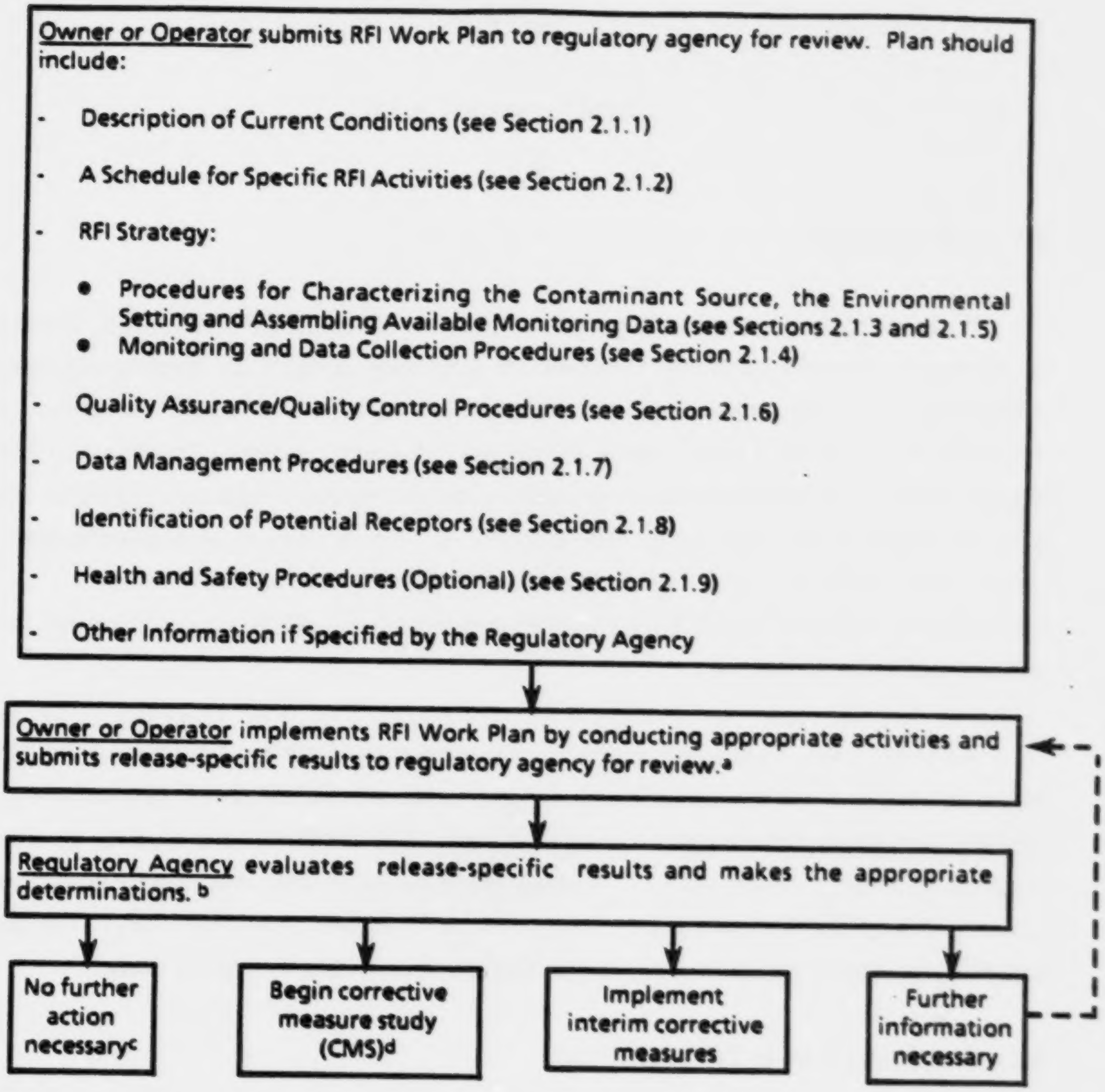
2.1 Introduction

If notified by the regulatory agency that an RFI must be conducted, the owner or operator should initiate a series of activities aimed at supplying specific information on the identified, suspected or known releases of concern. Such activities can include release verification and characterization. Conducting the RFI should follow a logical sequence of actions involving the preparation and submittal of a RFI Work Plan, including development of a monitoring approach (phased, if necessary), performance of investigatory tasks, submission of results, and interactions with the regulatory agency on courses of further action. The overall RFI process is shown in Figure 2-1.

As indicated previously, each RFI situation is likely to be unique in various respects, including the unit or units releasing, the media affected, the extent of the release, the potential for inter-media impacts, the amount and quality of existing information, and other factors. The amount of work that may be involved in the RFI, and therefore the content of the RFI Work Plan, will also likely vary. This section provides guidance concerning the general content of the RFI Work Plan.

2.2 Preparation of an RFI Work Plan

The RFI Work Plan is a detailed plan that the facility owner or operator should develop and follow throughout the RFI that will lead to characterization of the nature, extent, and rate of migration of a release of hazardous waste or hazardous constituents. This plan consists of a number of components that may be developed and submitted either concurrently or sequentially in accordance with the schedule specified in the permit or compliance order. These components are shown in the top box of Figure 2-1. Development and, therefore, submittal of specific plan components (e.g., detailed monitoring procedures) may not be possible until



Owner or Operator submits RFI Work Plan to regulatory agency for review. Plan should include:

- Description of Current Conditions (see Section 2.1.1)
- A Schedule for Specific RFI Activities (see Section 2.1.2)
- RFI Strategy:
  - Procedures for Characterizing the Contaminant Source, the Environmental Setting and Assembling Available Monitoring Data (see Sections 2.1.3 and 2.1.5)
  - Monitoring and Data Collection Procedures (see Section 2.1.4)
- Quality Assurance/Quality Control Procedures (see Section 2.1.6)
- Data Management Procedures (see Section 2.1.7)
- Identification of Potential Receptors (see Section 2.1.8)
- Health and Safety Procedures (Optional) (see Section 2.1.9)
- Other Information if Specified by the Regulatory Agency

Owner or Operator implements RFI Work Plan by conducting appropriate activities and submits release-specific results to regulatory agency for review.[a]

Regulatory Agency evaluates release-specific results and makes the appropriate determinations.[b]

No further action necessary[c]
Begin corrective measure study (CMS)[d]
Implement interim corrective measures
Further information necessary

[a] In some cases, existing information may be adequate to characterize specific releases.

[b] The owner or operator also has a continuing responsibility to identify and respond to emergency situations and to define priority situations that warrant interim corrective measures.

[c] No further action will be necessary where a suspected release is shown to not be an actual release based on an adequate amount of monitoring data or where release concentrations are shown to be below levels of concern for a sufficient period of time.

[d] Implies release concentrations were observed to be equal to or above health and environmental assessment criteria, or that there was a reasonable likelihood of this occuring.

FIGURE 2-1. RCRA FACILITY INVESTIGATION (RFI) PROCESS.

adequate information on the contaminant source and environmental setting is gathered and evaluated. Discussion on RFI reporting and schedules between the owner or operator and regulatory agency is encouraged.

The owner or operator should be guided by the information contained in the RFA Report and the conditions specified in the permit or compliance order in developing the RFI Work Plan. These conditions will usually indicate which units and releases are to be addressed in the RFI (based on the findings of the regulatory agency during the RFA), as well as which media are of concern. In most cases, the information contained in the RFA Report and the conditions specified in the order or permit will enable the owner or operator to develop a sufficiently focused RFI Work Plan. However, if additional guidance is needed by the owner or operator, consultation with the regulatory agency is advised.

2.2.1 Description of Current Conditions

As part of the RFI Work Plan, the owner or operator should provide background information pertinent to the facility, contamination, and interim corrective measures as described below. The data gathered during any previous investigations or inspections and other relevant data should be included. The owner or operator should consult with the regulatory agency to determine if any of these information items are irrelevant or have already been submitted in an appropriate format for other purposes (e.g., contained in a RCRA permit application).

2.2.1.1 Facility Background

The owner or operator should summarize the regional location, pertinent boundary features, general physiography, hydrogeology, and historical use of the facility for the treatment, storage or disposal of solid and hazardous waste. This information should include the following:

- Map(s) depicting the following:
    - General geographic location;

- Property lines, with the owners of all adjacent property clearly indicated;

- Topography and surface drainage (with an appropriate contour interval and a scale of 1 inch = 100 feet) depicting all waterways, wetlands, floodplains, water features, drainage patterns, and surface-water containment areas;

- All tanks, buildings, utilities, paved areas, easements, rights-of-way, and other features;

- All solid or hazardous waste treatment, storage or disposal areas active after November 19, 1980;

- All known past solid or hazardous waste treatment, storage or disposal areas regardless of whether they were active on November 19, 1980;

- All known past and present product and waste underground tanks or piping;

- Surrounding land uses (residential, commercial, agricultural, recreational); and

- The location of all production and ground-water monitoring wells. These wells shall be clearly labeled and ground and top of casing elevations and construction details included (these elevations and details may be included as an attachment).

All maps should be consistent with the requirements set forth in 40 CFR §270.14 and be of sufficient detail and accuracy to locate and report all current and future work performed at the site including;

- A history and description of ownership and operation, solid and hazardous waste generation, treatment, storage and disposal activities at the facility;

- Approximate dates or periods of past product and waste spills, identification of the materials spilled, the amount spilled, the location where spilled, and a description of the response actions conducted (local, state, or federal response units or private parties), including any inspection reports or technical reports generated as a result of the response; and

- A summary of past permits requested and/or received, any enforcement actions and their subsequent responses and a list of documents and studies prepared for the facility.

2.2.1.2 Nature and Extent of Contamination

The Owner or Operator should describe any existing information on the nature and extent of releases, including:

- A summary of all possible source areas of contamination. This, at a minimum, should include all regulated units, solid waste management units, spill areas, and other suspected source areas of contamination. For each area, the owner or operator should identify the following:
    - Location of unit/area (which should be depicted on a facility map);
    - Quantities of solid and hazardous wastes;
    - Hazardous waste or constituents, to the extent known; and
    - Identification of areas where additional information is or may be necessary.
- A description of the degree and extent of contamination. This should include:
    - Available monitoring data and qualitative information on locations and levels of contamination at the facility.
    - All potential migration pathways including information on geology, pedology, hydrogeology, physiography, hydrology, water quality, meteorology, and air quality; and

- The potential impact(s) on human health and the environment, including demography, ground-water and surface-water use, and land use.

2.2.1.3 Implementation of Interim Corrective Measures

The owner or operator should document interim corrective measures which were or are being undertaken at the facility. This should include:

- Objectives of the interim measures, including how the measure is mitigating a potential threat to human health and the environment and/or is consistent with and integrated into any long term solution at the facility;
- Design, construction, operation, and maintenance requirements;
- Schedules for design, construction and monitoring; and
- Schedule for progress reports.

2.2.2 Schedule for Specific RFI Activities

In the RFI Work Plan, the owner or operator should supply a schedule for completing the RFI within the time frame of the order or permit schedule of compliance. The schedule should be as specific as possible and should indicate dates for submittal of the various components of the RFI Work Plan, dates for starting and accomplishing specific tasks associated with the RFI, and dates for reporting information from specific tasks to the regulatory agency.

2.2.3 Procedures for Characterizing the Contaminant Source and the Environmental Setting

Prior to establishing monitoring procedures to provide data on the release, certain information should be acquired to determine constituents of concern and to determine appropriate sampling locations. Two key areas should be addressed: Source characterization (i.e., waste and unit), and characterization of the environmental setting. These areas are described generally below. They also are described in detail in each of the media-specific sections.

2.2.3.1 Contaminant Source Characterization

Characterization of the unit(s) and associated waste may be necessary to identify applicable monitoring constituents or useful indicator parameters for the release characterization. Design and operational information on the unit, such as unit size and amount of waste managed therein, may be necessary to determine release rates.

In some cases, adequate characterization of the waste in the unit can be made by evaluating existing waste management records or data on the process generating the waste. In other cases, a sampling and analysis effort may be necessary. If so, the owner or operator should define the sampling and analysis effort in regard to:

- Constituents, analytical methods, and the rationale for their selection;
- Sampling methods, sampling locations, equipment, and schedule; and
- Pertinent QA/QC procedures to assure valid waste characterization.

Identification of monitoring constituents and use of indicator parameters is detailed in Section 3 and supported by Appendix B. Waste and unit characterization methods, including sampling, are described in Section 7. QA/QC procedures are described in Section 4.

Unit characterization should include information such as construction procedures and materials, and liner specifications, if applicable. Such information may be important in evaluating the probable degree of contamination from the unit, and consequently, the probable type and severity of the release.

Waste characterization will not always provide complete information for use in identifying monitoring constituents. This may be especially true for old units, where significant degradation of constituents may have occurred, and for those units that have received many different types of waste, where it is difficult to be sure that all wastes in the unit were sampled and analyzed. The owner or operator should be aware of these possibilities. Further guidance on appropriate procedures in these cases is provided in Sections 3 and 7.

2.2.3.2 Environmental Setting Characterization

Characterization of the environmental setting may be necessary to determine monitoring locations (i.e., contaminant pathways) and to aid in defining the boundaries of the contaminated area. Techniques for characterizing the environmental setting are media-specific and are described in Volumes II and III of this Guidance. Examples of environmental information which may be required are wind speed and direction, subsurface stratigraphy, and surface water body volumes and flow rates.

2.2.4 Monitoring and Data Collection Procedures

Specific monitoring procedures should be identified in the RFI Work Plan to characterize each release of concern. These procedures should indicate the proposed approach for conducting the investigation and should account for the following:

- Historical information and/or information gathered during the characterization of the contaminant source and the environmental setting;
- An approach for implementation, including the type of information to be collected;
- Description of the monitoring network; and
- Description of monitoring activities (e.g., sampling, meteorological monitoring).

Monitoring procedures may include a phased approach for release characterization as described in the media-specific sections of this Guidance. The initial phase may include a limited monitoring effort followed by subsequent phases, if necessary. The design of subsequent monitoring phases may be based on information gathered during a prior phase; therefore, revisions to the monitoring procedures may become necessary as the RFI progresses. The phased approach may be particularly useful in cases where a suspected release was identified by the regulatory agency as a result of the RFA process. In this case, the first monitoring phase may be designed to provide for release verification as well as the first step for release characterizaton. A phased approach may therefore provide a more focused investigation. If revisions to a proposed phased approach become necessary, documentation should be submitted to the regulatory agency to support such changes.

2.2.5 Assembling Existing Data to Characterize the Contaminant Release

The owner or operator should assemble and review existing analytical and monitoring data pertinent to the release and medium of concern. This information can be used to determine the need for and to plan the extent of additional monitoring. Only data that have been collected using reliable methods and documented QA/QC procedures should be used as the basis for planning additional efforts. The amount and quality of existing data will determine the need for additional monitoring information on the release. Sources of such data include:

- Information supplied by the regulatory agency with the permit conditions or compliance order;
- The RFA report;
- Facility records;
- The facility's RCRA permit application;
- State and local government agency files, and
- EPA CERCLA site reports (e.g., Records of Decisions).

2.2.6 Quality Assurance/Quality Control (QA/QC) Procedures

The use of properly documented and implemented QA/QC procedures for monitoring activities (including sampling and analysis) is an essential part of the RFI Work Plan. It is important to ensure that data generated during the investigation are valid (i.e., supported by documented procedures) such that they can be used with confidence to support determinations regarding the need for and design of subsequent monitoring, the need for interim corrective measures and the need for a Corrective Measure Study. These procedures are used to describe and document data quality and include such activities as:

- Defining sampling and analytical techniques;
- Confirming and documenting correct sample identity;
- Establishing precision and accuracy of reported data;
- Documenting all analytical steps in determining sample identity and constituent concentrations;
- Establishing detection limits for constituents of concern; and
- Establishing any bias arising from field sampling or laboratory analytical activities.

Another important aspect of QA/QC is to ensure the use of qualified personnel (e.g., licensed or certified) to conduct or oversee various parts of the investigation. QA/QC procedures are described in Section 4.

2.2.7 Data Management Procedures

Data management procedures should be included as part of the RFI Work Plan for organizing and reporting investigation data and results. Satisfactory presentation of investigation results to the regulatory agency is essential in characterizing and interpreting contaminant releases. Guidance on these procedures is presented in Section 5.

2.2.8 Identification of Potential Receptors

The owner or operator should provide in the RFI Work Plan, as specified by the regulatory agency in the permit or order, information describing the human populations and environmental systems that may be susceptible to contaminant exposure from the facility. Such information may include:

- Existing and possible future use of ground water, including the type of use (e.g., municipal and/or residential drinking water, agricultural, domestic/non-potable and industrial);

- Location of ground-water users, including wells and discharge areas;

- Existing and possible future uses of surface waters draining the facility, including domestic and municipal uses (e.g., potable and lawn/gardening watering), recreational (e.g., fishing and swimming), agricultural, industrial and environmental (e.g., fish and wildlife populations) uses;

- Human use of or access to the facility and adjacent lands, including recreational, hunting, residential, commercial, zoning, and the relationship between population locations and prevailing wind direction;

- A description of the biota in surface water bodies on, adjacent to, or which can be potentially affected by the release;

- A description of the ecology on and adjacent to the facility;

- A demographic profile of the human population who use or have access to the facility and adjacent land, including age, sex, sensitive subgroups (e.g., schools, nursing homes), and other factors as appropriate; and

- A description of any endangered or threatened species near the facility.

This information can be used to determine whether any interim corrective measures may be necessary at the facility. If populations are currently being adversely exposed or such exposure seems imminent, interim corrective measures may be necessary. Further information regarding interim corrective measures is provided in Section 8 (Health and Environmental Assessment).

Receptors can be affected by the transfer of a release from one medium to another. Apparent or suspected inter-media transfers of contamination, as identified in the permit or order, should be addressed in the RFI Work Plan. Table 2-1 illustrates some potential inter-media contaminant transfers and pathways. In examining the extent of a release, the owner or operator may be directed to collect sufficient information to allow the identification of potential inter-media transfers.

Potential situations where inter-media contaminant transfer may be important may arise through common usage of the contaminated medium. For example, drinking of ground or surface waters contaminated with volatile constituents poses an obvious hazard. Less obvious is the inhalation hazard posed by showering with such contaminated waters. Situations such as this should also be considered when determining the need for interim corrective measures.

The guidance presented in the media-specific sections (Volumes II and III) addresses potential areas for inter-media transfer. The guidance also identifies situations in which contamination of more than one media can be characterized, to some extent, using common procedures. For example, soil-gas analyses, such as those conducted using an organic vapor analyzer (OVA), can be used to monitor for subsurface gas (e.g., methane), as well as to indicate the overall extent of certain types of contaminant releases to ground water.

2.2.9 Health and Safety Procedures

Health and safety procedures may be included as part of the RFI Work Plan. The owner or operator is advised to understand, use and document health and safety procedures describing the efforts that will be taken to ensure the health and safety of the investigative team and others (e.g., the general public) during the RFI. The owner or operator should also be aware that on December 19, 1986, the

TABLE 2-1. POTENTIAL INTER-MEDIA CONTAMINANT TRANSFER PATHWAYS

Release Media	Potential Recieving Media	Transfer Pathways
Air	● Soil ● Surface Water	- Deposition of particles - Atmospheric washout
Soil	● Ground Water ● Subsurface Gas ● Surface Water	- Migration through the unsaturated zone - Migration through the soil - Overland runoff
Ground Water	● Surface Water ● Subsurface Gas	- Ground-water discharge - Volatilization
Surface Water	● Ground water ● Air ● Soil	- Ground-water recharge - Volatilization - Deposition of floodplain sediments
Subsurface Gas	● Air ● Soil	- Venting through soil - Migration through soil

Occupational Safety and Health Administration (OSHA) issued, an interim final rule on hazardous waste site operations (29 CFR 1910.120) which specifically requires certain minimum standards concerning health and safety for anyone performing activities at CERCLA sites, RCRA sites, or emergency response operations. Further discussion on this topic is provided in Section 6.

2.3 Implementation of the RFI Work Plan

After review of the RFI Work Plan by the regulatory agency, the owner or operator should implement the plan as directed. In some cases, adequate information may exist to characterize specific releases and an extensive monitoring effort may not be necessary. The extent of monitoring will depend on the amount and quality of existing information and the nature of the release. Results of investigative activities should be submitted to the regulatory agency according to the RFI Work Plan schedule. Further guidance on specific reports which may be required is provided in Section 5.

The owner or operator has a continuing responsibility to identify and respond to emergency situations and to define priority situations that may warrant interim corrective measures. Interim corrective measures may be necessary if receptors are currently being exposed to release constituents or if such exposure seems imminent. These situations may become evident at any point in the RFI process. The owner or operator should contact the regulatory agency immediately if any such situation becomes apparent. Further information regarding the evaluation of the results of release characterization is presented in Section 8.

2.4 Evaluation by the Regulatory Agency

The regulatory agency will evaluate release-specific results of the RFI submitted by the owner or operator in order to make determinations for further action. Such determinations may include:

- No further action is necessary at that time;

- Further information on a release is necessary. The owner or operator will be advised to initiate additional monitoring activities;

- Interim corrective measures are necessary; or

- Adequate information is available to conclude that a Corrective Measures Study (CMS) is necessary.

The regulatory agency may elect to be present at the facility to observe any phase of the release investigation. As indicated previously, close coordination between the owner or operator and the regulatory agency is essential throughout the RFI process.

SECTION 3

GENERAL STRATEGY FOR RELEASE INVESTIGATION

3.1 Introduction

An investigation of releases from solid waste management units requires various types of information. This information is specific to the waste managed, unit type, design, and operation, the environment surrounding the unit or facility, and the medium to which contamination is being released. Although each medium will require specific data and methodologies to investigate a release, a general strategy for this investigation can be described. This strategy can be considered to consist of two elements:

- Collection and review of data to be used in developing a conceptual model of the release that can be used to plan and develop monitoring procedures. These data could include existing information on the facility/unit or related monitoring data, data which can be gathered from outside sources of information on parameters affecting the release, or the gathering of new information through such mechanisms as aerial photography or waste characterization.

- Formulation and implementation of field investigations, sampling and analysis, and/or monitoring procedures designed to verify suspected releases (if necessary), and to evaluate the nature, extent, and rate of migration of verified releases.

As stated in Section 2, two components of the RFI Work Plan will address these elements. These are:

- Procedures to characterize the contaminant source and the environmental setting; and

- Monitoring procedures.

Sections 3.4 and 3.5 provide general guidance on these procedures. First, Section 3.2 outlines the general strategy suggested for all release investigations and Section 3.3 briefly discusses concepts concerning data quality designed to ensure that the data collected during the investigation will adequately support the decisions that will eventually be made regarding the need for corrective measures. Section 3.6 provides guidance for formulating methods and monitoring procedures, and addresses monitoring constituents and indicator parameters, use of EPA and other methods, sampling considerations, and analytical methods and detection limits. Section 3.7 provides information concerning various decisions that may be made based on monitoring data and other information that is collected during the RFI process.

3.2 Phased Strategy for Release Investigations

Varying amounts of information will exist on specific releases and units at the start of the RFI process. In some instances, suspected releases may have been identified based on strong evidence that releases have occurred, but with little or no direct data confirming their presence. On the other end of the spectrum, there may be enough existing data at the start of the RFI to begin considering whether some form of corrective measure may be necessary.

This potentially broad spectrum of situations which may exist at the beginning of the RFI may call for a flexible, phased approach for the release investigation, begining with an evaluation of existing data and collecting additional data, as necessary to characterize the release source and the environmental setting. From such data a conceptual model of the release can be formulated in order to design a monitoring program capable of release verification and/or characterization.

The release characterization may be conducted in phases, if appropriate, with each monitoring phase building on the findings and conclusions of the previous phase. The overall level of effort and the number of phases for any given characterization effort depends on various factors including:

- The level of data and information available on the site;

- The complexity of the release (e.g., number of units, release pathways, affected media); and

- The overall extent of the release.

Given that many situations are likely to be unique with respect to the above factors, the number and intensity of each of the phases of the RFI process leading to eventual characterization and assessment against health and environmental criteria is also likely to be unique. Even though some RFI's may have several phases, it is important to make sure that the establishment of a phased approach does not result in undue delay of the RFI process.

Case Study No. 4 in Volume IV (Case Study Examples) provides an illustration of a phased characterization.

3.3 Data Quality and Use

Throughout the RFI process, it should be kept in mind that the data will be used in making comparisons to health and environmental criteria to determine whether a Corrective Measures Study or interim corrective measures may be necessary. Therefore, the data collected during the investigation needs to be of sufficient quality to support decisions as to the need for corrective measures. The data can also be used to help establish the scope and types of corrective measures to be considered in the Corrective Measures Study.

Qualitative or quantitative statements that outline the decision making process and specify the quality and quantity of data required to support decisions should be made early in the planning stages of the RFI. These "data quality objectives" are then used to design sampling and analytical plans, and to determine the appropriate level of quality assurance and control (QA/QC). As this subject is normally considered a QA/QC function, it is presented in more detail in the QA/QC Section (Section 4) of this document. It is discussed briefly here to stress the importance of defining the objectives of the investigation, and designing data gathering efforts to meet these objectives throughout the investigation.

3.4 Procedures for Characterizing the Contaminant Source and the Environmental Setting

Prior to establishing monitoring procedures, information on the contaminant source (i.e., waste and unit) and environmental setting may be required. The owner or operator should identify necessary data and formulate procedures to gather these data.

Data on the unit that may be required for release investigation includes such parameters as the physical size of the unit, the amount of waste in the unit, operational schedules, age, operational lifetime, and release controls. Data concerning the environmental setting that may be necessary is specific to the medium affected, and may include such information as climate, hydrogeologic setting, vegetation and topography. These and other important elements are described below, starting with a discussion of the importance of existing information.

Case Study Numbers 13, 20, 22, 23, 24 and 31 in Volume IV (Case Study Examples) provide examples of the techniques discussed below.

3.4.1 Sources of Existing Information

Useful existing data may be found in the following sources:

- The RCRA FAcility Assessment report. This report should provide information on the unit(s) known to be or suspected of causing a release to the environment and the affected media. It may also include data supporting the regulatory agency's release determinations. The owner or operator may wish to obtain the RFA report from the regulatory agency for use in scoping the RFI.

- Facility records and files. Other useful information may be available in facility records and files. This information may include data from required ground-water monitoring activities, results of required waste analyses, and other analytical results (e.g., tests run on wastes to determine such parameters as liner compatibility or free liquid composition). The owner or operator may have information on the characteristics of the waste in the units of concern from other in-house sources, such as waste reduction and engineering studies on the process(es) feeding the units, or from analyses performed in conjunction with other regulatory programs, such as the National Pollutant Discharge Elimination System permitting process or Clean Air Act Standards. Design and construction information may also be contained within facility files. For example, design and construction information for advanced wastewater treatment sysems may contain information on inactive units.

- RCRA Permit Application. Under current requirements, a RCRA permit application should include a description of the waste being managed at the facility (although not necessarily for all of the units of concern), descriptions of the units relevant to the permit, descriptions of the general environment within and surrounding the facility (including, descriptions of the subsurface stratigraphy), and design and operating information such as runon/runoff controls. A companion rule to the July 15, 1985, codification rule for Section 3004(u) will expand the information requirements under §270.14(d) for all solid waste management units to be located on the facility topographic map, and to contain information on unit type, dimensions and design, dates operated, and waste managed, to the extent available.

- State Construction Permit (e.g., industrial wastewater) files.

- Environmental or other studies conducted in conjunction with ownership changes.

- Interviews with facility personnel (current or retired).

- Environmental audit reports.

- Investigations for environmental insurance policies.

3.4.2 Waste and Unit Characterization

In addition to obtaining waste data on general parameters such as pH, density, and viscosity which may be needed to characterize a release to specific media (and which may also be useful in evaluating corrective measure technologies), the owner or operator should characterize the unit's waste to the compound-specific level. This characterization may serve as a basis for identifying monitoring constituents and indicator parameters for the media of concern. It should be noted that the owner or operator may be required to monitor for all potential constituents of concern for a given medium, unless it can be shown that only certain constituents could be released from the waste source. A detailed waste characterization, through the use of facility records and/or additional waste sampling and analysis, can be utilized to limit the number of constituents for which release monitoring must be performed during the RFI (See also Section 3.6.1).

Waste and unit characterization procedures should address:

- Existing sources of information on the unit and waste and their utility in characterizing of the waste source; and

- Methods for gathering data that are not presently available on the waste and unit.

In some cases the location of disposal areas (units) may not be obvious. Some of these disposal areas or units may have been buried and overgrown by trees or covered by structures such as buildings or parking lots. In such cases, use of geophysical techniques (e.g., ground-penetrating radar - See Appendix C) may be useful in locating old disposal areas containing materials such as discarded drums or buried tanks.

After evaluating existing data, the owner or operator may propose to collect additional waste and unit characterization information. In such cases, the owner or operator should propose procedures in the RFI Work Plan for:

- Sampling--This should include sampling locations, schedules, numbers of samples to be taken, and methods for collecting and storing samples.

- Analysis--This should include a listing of analytical constituents or parameters and the rationale for their selection, analytical methods, and identification of detection limits.

- QA/QC--This should include specific steps to be taken to ensure the viability and validity of data produced during a waste sampling effort.

- Data management--The owner or operator should describe data management procedures, including the format(s) by which data on the contaminant source will be presented to the regulatory agency and the various reports that will be submitted.

Further guidance on the types of information and methods to be used in gathering waste and unit data is given in Section 7.

3.4.3 Characterization of the Environmental Setting

Data on the environmental setting will generally be necessary for characterizing the release, and may also be helpful for evaluating various corrective measure technologies. The information necessary is specific to the site and medium receiving the release and is described in the media-specific sections (Sections 9 through 13). Some examples of the methods and techniques that may be used are:

- Direct media measurements--Direct media measurements can provide important information that can be used to determine the rate and extent of contaminant releases. For example, hydraulic conductivity measurements are essential in determining ground-water flow rates. Wind roses and patterns can be used in determining how far air contamination may migrate and is essential input for air dispersion models. Specific measurements that are helpful for investigating the rate and extent of releases are discussed in the media-specific sections (Sections 9 through 13) of this Guidance.

- Aerial photography--Aerial photography can provide information which can be helpful in determining the extent of contamination at a site.

Aerial photographic interpretation can aid in describing past and present contaminant sources, pathways, and effects. Information obtained can include ecological impacts (e.g., decaying vegetation), topography, drainage patterns, fracture traces, and other erosional features. The usefulness of aerial photography is discussed further in Appendix A.

- Geophysical techniques--Geophysical techniques can aid in characterizing subsurface conditions fairly rapidly with minimal disturbance of the site. Such characterization can provide information on physical (e.g., stratigraphy) and chemical (e.g., contaminant extent) conditions and can also be used to locate buried drums, tanks and other wastes. Geophysical techniques include electromagnetic induction, seismic refraction, electrical resistivity, ground penetrating radar, magnetic borehole methods, and other geophysical methods. These techniques can be particularly useful in determining appropriate sampling locations. However, these geophysical techniques are not always applicable at a particular site and do not provide detailed contaminant concentration data. Therefore, sampling will generally be necessary to provide data needed for adequately characterizing the release. Further details on these techniques are available in Section 10 on Ground Water, and in Appendix C (Geophysical Techniques).

- Surveying and mapping--Accoridng to the 40 CFR Part 270 requirements for RCRA permit applications, the owner or operator must provide a topographic map and associated information regarding the site. If an adequate topographic map does not exist, a survey may be necessary to measure and plot land elevations. Site-specific surveying and mapping can provide an effective means of expressing topographic features of an area useful in characterizing releases (e.g., subtle elevation changes and site drainage patterns). Surveying and mapping are discussed in further detail in Appendix A.

The owner or operator should describe in the RFI Work Plan:

- Specific techniques to be used in defining the environmental setting for the releases of concern at the facility;

- A rationale for the use of these techniques;
- Specific QA/QC procedures applicable to the proposed techniques;
- Procedures for managing and presenting the data; and
- The potential uses of the information obtained from this characterization.

3.4.4 Assembling Available Monitoring Data

The owner or operator should compile and assess available media-specific monitoring data as a means of determining additional data needs. It is conceivable, in certain instances, that available data will be sufficient to characterize a release and provide the basis for making a determination on the need for corrective measures. However, this conclusion would be valid only if available data are current, comprehensive, accurate, and supported by reliable QA/QC methods. Otherwise, the use of available data should be limited to planning additional monitoring efforts.

3.5 Use of Models

Mathematical and/or computer modeling may provide information useful to the owner or operator during the RFI and in the design of corrective measures. The information may prove useful in refining conceptualizations of the environmental setting, defining likely contaminant release pathways, and designing corrective measures (e.g., pumping and treating of contaminated ground water).

Because a model is often a mathematical representation of a complex physical system, simplified assumptions must be made about the physical system, so that it may fit into the more simplistic mathematical framework of the model. Such assumptions are especially appropriate, since the model assumes a detailed knowledge of the relevant input parameters (e.g., permeability, porosity, etc.) everywhere in the area being modeled. This is a limitation that must be considered because it would be impossible to obtain all the input parameters without disturbing and altering the physical system.

Because a model uses assumptions as to both the physical processes involved and the spatial and temporal variations in field data, the results produced by the model at best provide a qualitative assessment of the nature, extent, and rate of migration of a contaminant release. Because of the assumptions made, a large degree of uncertainty is inherent in most modeling simulations. Thus, modeling results should not be unduly relied upon in selecting precise monitoring locations or in designing corrective measures.

Use of predictive models during the RFI may be appropriate for guiding the general development of monitoring networks. Each of the media-specific sections identify where and how such predictive models may be used, and identify references containing specific models. For example, models are identified in the Surface Water Section (Section 13) for use in determining the extent of a monitoring system which may be required in a stream. Modeling results are generally not acceptable for expressing release concentrations in a RFI. An exception to this is the air medium (Section 12). Atmospheric dispersion models are suggested for use (especially when downwind monitoring is not feasible) in conjunction with emission rate monitoring in order to predict downwind release concentrations and to define the overall extent of a release.

Where a model is to be used, site-specific measurements should be collected and verified. The nature of the parameters required by a model varies from model to model and is a function of the physical processes being simulated (e.g., ground-water flow and/or contaminant transport), as well as the complexity of the model. In simulating ground-water flow, for example, the hydrogeologic parameters that are usually required include: hydraulic conductivity (vertical and horizontal); hydraulic gradient; specific yield (unconfined aquifer) or specific storage (confined acquifer); water levels in wells and nearby surface water bodies; and estimates of infiltration or recharge. In simulating contaminant transport in ground water, the physical and chemical parameters that are usually required include: ground-water velocity; dispersivity of the aquifer; adsorptive characteristics of the aquifer (retardation); degradation characteristics of the contaminants; and the amount of each contaminant entering the aquifer (source definition).

Model input parameters that can be determined directly should be measured with consideraiton given to selecting representative samples. Because the parameters cannot be measured continuously over the entire region but only at discrete locations, care should be taken when extrapolating over regions where there are no data. These considerations are especially important where the parameters vary significantly in space or time. The sensitivity of the model output both to the measured and assumed input parameters should be determined when evaluating modeling results. In addition, the ability of the model to be adequately calibrated (i.e., the ability of the model to reproduce current conditions), and to reproduce past conditions should be carefully evaluated in assessing the reliability of model predictions. Model calibration with observed physical conditions is critical to any successful modeling exercise.

Many models exist that may be applicable for use in the RFI. Since EPA is a public agency and models used by or for EPA may become part of a judicial action, EPA approval of model use should be restricted to those models that are publicly available (i.e., those models that are available to the public for no charge or for a small fee). The subset of models that are publicly available is quite large and should be sufficient for many applications. Publicly available models include those models developed by or for government agencies (e.g., EPA, USGS, DOE, NRC, etc.) and national laboratories (e.g., Sandia, Oak Ridge, Lawrence Berkeley, etc.), as well as models made publicly available by private contractors. Any publicly available model chosen should, however, be widely used, well documented, have its theory published in peer-reviewed journals, or have some other characteristics reasonably assuring its credibility. For situations where publicly available models are not appropriate, proprietary models (i.e., models not reasonably accessible for use or scrutiny by the public) should only be used where the models have been well documented and have undergone substantial peer review. Where these minimal requirements have not been met, the model will not be considered reliable.

The Graphical Exposure Modeling System (GEMS) may be particularly useful for various aspects of the RFI. GEMS is an interactive computer system developed by EPA's Office of Pesticides and Toxic Substances, that provides a simple interface to environmental modeling, physiochemical property estimation, statistical analysis, and graphic display capabilities, with data manipulation which supports all of these functions. Fate and transport models are provided for soil, ground water, air and surface water, and are supported by various datasets, including demographic, hydrologic, pedologic, geologic, climatic, economic and many others. Further information on GEMS may be obtained by calling EPA at (202) 382-3397 or 3929 or writing to EPA at the following address:

U.S. EPA
Office of Pesticides and Toxic Substances
Exposure Evaluation Division (TS-798)
401 M Street, S.W.
Washington, D.C. 20460

If the use a model is proposed to guide the development of a monitoring network, the owner or operator should describe how the model works, as well as to explain all assumptions used in calibrating and applying the model to the site in question. In addition, the model and all related documentation should be made available to the regulatory agency for review and scrutiny.

Case Study Numbers 6, 9, 14 and 29 in Volume IV (Case Study Examples) illustrate the use of various models that may be applied during the RFI.

3.6 Formulating Methods and Monitoring Procedures

The RFI Work Plan should describe monitoring procedures which address the following items on a release-specific basis:

- Monitoring constituents of concern and other monitoring parameters (e.g., indicators);
- Sampling locations and frequency;
- Sampling methods;
- Types of samples to be collected;
- Analytical methods; and

- Detection limits.

These items are discussed below.

3.6.1 Monitoring Constituents and Indicator Parameters

The selection and use of monitoring constituents and indicator parameters is a site-specific process and depends on several factors, including the following:

- The phase of the release investigation (e.g., verification, characterization);
- The medium or media being investigated;
- The degree to which verifiable historical information exists on the unit or release being investigated;
- The degree to which the waste in the unit(s) has been characterized through sampling and analysis;
- The extent of the release;
- The concentration of constituents within the contaminated media; and
- The potential for physical, chemical, or biological transformations (e.g., degradation) of waste or release constituents.

The general strategy for the selection of specific monitoring constituents starts with a large universe list of constituents (i.e., 40 CFR Part 261, Appendix VIII). Based on site-specific considerations (e.g., the contaminated media, sampling and analysis of waste from the unit or industry-specific information), this list may be shortened to an appropriate set of monitoring constituents. Constituents initially deleted as a result of this process may have to be analyzed at selected locations during and/or following the RFI, especially if a Corrective Measures Study is found to be necessary.

The discussion below explains the use of the three lists presented in Appendix B for selecting monitoring constituents and supplemental indicator parameters:

List 1 in Appendix B identifies indicator parameters that are recommended for release verification or characterization for the five environmental media discussed in this Guidance. They can be useful regardless of site-specific considerations. This list was developed based on a review of RCRA and CERCLA guidances, as well as information obtained during RCRA and CERCLA site investigations. These indicator parameters should be used in the RFI unless the owner or operator can show that their use will not be helpful. For example, although total organic carbon (TOC) and total organic halogen (TOX) are listed as indicator parameters for ground water, their use may not be warranted for releases consisting primarily of inorganic (e.g., heavy metal) contamination.

List 2 in Appendix B is a master list of potential hazardous constituents that may, at one time or another, have to be monitored during an RFI. It contains the 40 CFR Part 261, Appendix VIII list of hazardous constituents in the left-hand column. The five environmental media columns contain X's where there is a reasonable probability, based on physical or chemical characteristics, of a particular constituent being present in the given medium. However, constituents not containing an X for a particular medium may still be present in that medium, despite a relatively low probability of their presence. Therefore, the regulatory agency may add such constituents for monitoring when appropriate. List 2 was derived through consultation with various EPA program offices and through examination of existing regulations. The rationale for identifying specific Appendix VIII constituents for the various media is explained below:

- Reactivity with water. Those constituents that react with or decompose in water were not marked with an X in the water-related columns.

- Existence of viable analytical techniques for a constituent in a specific medium. In many cases, constituents were not included for a specific medium because valid analytical methodologies are not currently available for that particular constituent/medium combination. In some cases, standard reference materials are not available for the analysis.

[Note that the above two criteria describe the primary rationale used to develop the 40 CFR Part 264, Appendix IX list of ground-water monitoring constituents. Hence, the ground and surface water columns in List 2 are based on the final Appendix IX constituent list.]

- Recommendations from other EPA program offices. Offices concerned with the release of hazardous constituents to various media were consulted for recommendations on the analytes of primary concern. Appendix VIII hazardous constituents regarded by EPA's Office of Air Quality Planning and Standards (OAQPS) as being of primary concern for release to air are identified in the air column in List 2.

- Background information. Analytes recommended for subsurface gas releases were chosen due to their predominance in past studies of this problem. The primary sources used for the subsurface gas medium are:

  U.S. EPA. Technical Guidance for Corrective Measures -Subsurface Gas. Prepared by SCS Engineers for U.S. EPA, Office of Solid Waste. Washington, D.C. 20460.

  South Coast Air Quality Management District. December 1986. Hazardous Pollutants in Class II Landfills. U.S. EPA, Region IX. San Francisco, CA 94105.

- The soil column includes constituents that may be present in both saturated and unsaturated soil. The column generally identifies constituents that are also identified for the ground and surface water media, but contains additional constituents which are normally analyzed during soil contamination investigations (e.g., hydrogen sulfide and other gasses) and certain other compounds that can be highly attenuated in soil (e.g., polyaromatic hydrocarbons).

An RFI may involve the investigation of waste which is hazardous by characteristic, as well as containing specific hazardous constituents. For example, methane, which is not an Appendix VIII hazardous constituent, is shown as an ıdicator parameter in List 1 for releases of subsurface gas. Because methane at sufficient concentrations possesses explosive or reactive properties, it can be hazardous based on the reactivity characteristic (40 CFR 261.23). Hence, subsurface gas may be the subject of an RFI even if specific hazardous constituents are not identified in the release.

List 3 in Appendix B is an industry-specific list. This list identifies categories of constituents, based on the classification presented in the 3rd Edition of EPA's Test Methods for Evaluating Solid Waste (EPA/SW-846), that may be present if wastes from a given industry are contained in the releasing unit. The EPA/SW-846 chemical classifications for these categories are reprinted as a supplement to List 3. List 3 applies to all media and may be used in conjunction with List 2 to identify industry-specific constituents that have a reasonable probability of being present in a particular medium. List 3 was derived from a review of the Development Documents for Effluent Guidelines Limitations prepared for various industries under EPA's National Pollutant Discharge Elimination System, information received from several EPA Regional Office Hazardous Waste Programs, and other references, as indicated in Appendix B. It does not cover all industries which may be subject to an RFI. The Development Documents for Effluent Guidelines Limitations are available for the 30 industries identified in List 3, and may be obtained from the National Technical Information Service (NTIS).

[Note that the chemical categories upon which List 3 are based are not mutually exclusive. If a category is identified as being appropriate for an industry, all constituents with~~in the category should be monitored~~ regardless of whether the constituent is contained in other categories.]

The use of the Appendix B lists in developing and implementing the general investigation strategy is described below.

The phase of the release investigation is a very important consideration. For example, the use of indicator parameters along with specific hazardous constituents, can be helpful in verifying the presence of a suspected release. However, indicators alone are not adequate in showing the absence of a release, partially because of their relatively high detection limits (i.e., generally 1000 ug/l versus 10 to 20 ug/l for specific constituent analyses), and because indicator parameters do not account for all classes of constituents that may be present. Verification of the absence of a release should therefore always be supported by specific hazardous constituent analyses.

For the same reasons, indicator parameters should not form the sole basis for release characterization, especially at locations in the release where indicator concentrations are close to detection limits. Indicator parameters may be particularly useful in mapping large releases, but should always be used in conjunction with specific monitoring constituents.

Specific monitoring constituents and indicator parameters may also need to be modified as the investigation progresses, because physical, chemical, and biological degradation may transform constituents as the release ages or advances. When chemicals degrade, they usually degrade into less toxic, more stable species. However, this is not always the case. For example, one of the degradation products of trichloroethylene is vinyl chloride. Both of these chemicals are carcinogens. Information on degradation can be found in the environmental literature. Particular references include:

> U.S. EPA. 1985. Atmoshperic Reaction Products from Hazardous Air Pollutant Degradation. NTIS PB85-185841. Washington, D.C. 20460.
>
> U.S. EPA. 1984. Fate of Selected Toxic Compounds Under Controlled Redox Potential and pH Conditions in Soil and Sediment Water Systems. NTIS PB84-140169. Washington, D.C. 20460.

This topic is discussed in more detail later in this section and in each of the media-specific sections.

After a release is adequately characterized in terms of concentrations of hazardous constituents (or hazardous characteristics), a comparison of these concentrations to EPA-verified health and environmental criteria will be made (see Section 8). Although this comparison may involve a shortened list at this stage of the investigation, all potential monitoring constituents (even those that were deleted earlier in the process) may need to be analyzed at selected monitoring locations to verify their presence or absence.

The medium or media being investigated is also an important consideration in the identification of monitoring constituents. For example, non-volatile constituents may be poor candidates for monitoring of an air release, unless wind-blown particulates are of concern. List 2 in Appendix B has been developed to aid in identifying those constituents most likely to be measurable in each medium of concern.

Historical information (e.g., records indicating the industry from which wastes originated) may be useful in selecting monitoring constituents. List 3 in Appendix B may be helpful in identifying classes of constituents that may be of concern if a particular industry can be identified.

Waste sampling and analysis (see Section 7) may be performed to tailor the initial list of monitoring constituents. Although complete waste characterization is recommended in most cases, this may not always be possible or desirable (e.g., for a large unit in which many different wastes were managed over a long period of time or in cases where wastes have undergone physical and/or chemical changes over a long time period). A complete historical waste characterization in such cases would not be possible. Other cases where waste sampling and analysis would generally be inadvisable are where the waste is highly toxic (e.g., nerve gas) or explosive (e.g., disposed munitions). In these cases, it may be more appropriate to sample the environmental medium of concern at locations expected to indicate the highest concentrations. Such sampling activities should be performed following appropriate health and safety procedures (see Section 6).

The extent of the release may also dictate, to some degree, the selection of monitoring constituents. For apparently small releases (e.g., five square yards of contaminated soil), it may be reasonable to base all analyses on specific monitoring constituents. For larger releases, the use of indicator parameters along with specific monitoring constituents may be a better approach. In this case, an appropriate balance between indicator parameters and monitoring constituents is advisable.

The concentrations of hazardous constituents within a contaminated medium may affect the usefulness of indicator parameters. For example, TOC and TOX may not be useful where their detection limits are not sensitive enough to detect the presence of the specific hazadous constituents of concern. In such cases, monitoring for specific constituents using more sensitive methods (e.g., GC/MS) is advisable.

In addition, the potential for physical, chemical, or biological transformations (e.g., degradation) of constituents should also be considered in identifying monitoring constituents. Biodegradation may be of particular importance for the soil and surface water media. For example, trichloroethylene present in a waste unit or medium for an adequate period of time, can degrade to vinyl chloride and other products. Such products may be present at higher concentrations than the parent trichloroethylene and may also be more toxic. Therefore, the selection of monitoring constituents should consider the potential for constituents to be transformed over time and space. Each of the media-specific sections contains a discussion of physical, chemical, and biological transformation mechanisms.

Another approach that may be taken in selecting monitoring constituents for a particular medium is to use physical and chemical property data, such as the octanol/water partition coefficient or solubility, to predict which constituents may be present in a given medium. Further guidance on the use of this approach, including tables presenting data on relevant physical and chemical properties of various constituents, is presented in the following reference:

> U.S. EPA. October, 1986. Superfund Public Health Evaluation Manual. EPA 540/1-86/060. Office of Emergency and Remedial Response. Washington, D.C. 20460.

Case Study Numbers 2, 16, 18, 21 and 22 in Volume IV (Case Study Examples) illustrate application of the concepts discussed above.

3.6.2 Use of EPA and Other Methods

As described in the proceeding sections of this document, and in the media-specific Sections (Sections 9 through 13), many different types of methods may be employed in conducting the RFI. These include methods for sampling, quality assurance and control, and field operations, as well as methods for physical, biological, and chemical analyses. These methods were developed by various organizations, including EPA, other Federal and State Agencies, and from "standard-setting" organizations (e.g., ASTM, American Society for Testing and Materials). Some of these methods are final, while others are in draft or proposed status. As discussed previously, the RFI Work Plan should propose methods which best suit the needs of the situation under investigation. Guidance in the following sections, and in the media-specific sections, is given on methods which are recommended in certain situations, including appropriate references. The following discussion highlights some general guidelines to follow in the selection of methods:

- Use of EPA Methods:

  EPA recently published the 3rd Edition of its testing manual for solid waste (U.S. EPA. 1986. Test Methods for Evaluating Solid Waste. EPA/SW-846, GPO No. 955-001-00000-1), generally known as SW-846. This manual provides quality assurance and control methods, analytical methods, physical and chemical property test methods, sampling and monitoring methods. These methods are acceptable for the RFI and contain guidance on unique problems which may be encountered during solid and hazardous waste investigations. Where possible, it is recommended that SW-846 (or equivalent) methods be used over other available methods. SW-846, however, may not provide all methods that may be applicable in certain situations. In such cases, other EPA methods manuals (including EPA Regional Office methods manuals) may be used. One such document that should be particularly useful is EPA's Compendium of Field Operations Methods, developed by the Office of Emergency and Remedial Response (OSWER Directive No. 9355.0-14, 1987). This document provides discussions of various methods which can be applied in field investigations, and includes general considerations for project planning, quality assurance and control, and sampling design. Specific methods presented include:

  - Rapid field screening procedures (e.g., OVA meters, HNu detectors);

  - Drilling in soils;

- Test pits and excavation;
- Geological reconnaissance;
- Geophysics;
- Ground-water monitoring;
- Physical and chemical properties;
- Surface hydrology;
- Meteorology;
- Biology and Ecology/Bioassay and Biomonitoring; and
- Surveying, Photography, and Mapping.

- Use of Other Federal or State Methods:

The Occupational Safety and Health Administration (OSHA), the Food and Drug Administration (FDA), and several other Federal agencies have developed methods and methods manuals for specific applications. In addition State and EPA Regional Offices have also developed methods and methods manuals. These methods may also be used during release investigations, if appropriate. The media-specific sections of this Guidance identifies where such methods may be particularly applicable.

- Use of other Methods:

There are several "standard-setting" organizations involved in the development of test methods for various applications. One such organization, the American Society for Testing and Materials (ASTM), publishes test methods and other standards in their Annual

Book of ASTM Standards, which is updated yearly. Many of ASTM's methods may be applicable for use in the RFI; however, if comparable EPA methods exist, these methods are preferred.

Many ASTM and EPA methods are similar and some are identical. The primary reason for this is that many EPA methods are derived from ASTM Methods. Some of ASTM's methods are adopted by EPA in toto. EPA's Compendium of Field Operations Methods, for example, contains many ASTM methods. Many ASTM methods are contained in that compendium and can be used during a RFI. Where comparable, but not identical, EPA and ASTM methods exist, EPA methods should be used because they often contain important information which is necessary for regulatory purposes.

Although ASTM's Committee D-34 on Waste Disposal, has only published several final methods (ASTM. 1986 Annual Book of ASTM Standards. Volume 11:04), it has many other methods currently in various stages of development. Several methods under development which may be applicable to the RFI process are expected to be finalized and available shortly.

Other organizations are also involved in the development and standardization of test methods. Many industrial and environmental association methods can also be used during an RFI. EPA's Compendium of Field Operations Methods identifies several of these.

All methods proposed for use by the owner or operator should be clearly described and adequately referenced.

3.6.3 Sampling Considerations

This section discusses several considerations important in designing a sampling plan, including sample types, and pertains to sampling of the waste source and the affected environmental media. Section 7 contains additional guidance on waste source sampling. A general discussion of sampling equipment and procedures is presented in EPA's SW-846. Other guidances containing general information that can be used in designing a sampling plan include the following:

U.S. EPA. 1987. Compendium of Field Operations Methods. Office of Emergency and Remedial Response. OSWER Directive No. 9335.0-14. Washington, D.C. 20460.

U.S. EPA. July 24, 1981. RCRA Inspection Manual. Section V. Office of Solid Waste. Washington, D.C. 20460.

U.S. EPA. June, 1985. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response. NTIS PB85-238616. Washington, D.C. 20460.

U.S. EPA. May, 1984. Soil Sampling Quality Assurance Users Guide. CR810550-01. NTIS PB84-198621. Washington, D.C. 20460.

3.6.3.1 General Sampling Considerations

Various methods exist for obtaining acceptable samples of waste and for each medium described in this document. Each of the media-specific sections (Sections 9 through 13) describes appropriate methods. The RFI Work Plan should propose methods which best suit the needs of the sampling effort. The following criteria should be considered in choosing such methods:

- Representativeness--The selected methods should be capable of providing a true representation of the situation under investigation.

- Compatibility with Analytical Considerations--Sample integrity must be maintained to the maximum extent possible. Errors induced by poorly selected sampling techniques or equipment can result in poor data quality. Special consideration should be given to the selection of sampling methods and equipment to prevent adverse effects during analysis. Materials of construction, sample or species loss, and chemical reactivity are some of the factors that should receive attention.

- Practicality--The selected methods should stress the use of simple, practical, proven procedures capable of being used in or easily adapted to a variety of situations.

- Simplicity and Ease of Operation--Because of the nature of the material to be sampled, the physical hazards which may be encountered during sampling, and the wearing of safety equipment, the proposed sampling procedures should be relatively easy to follow and equipment simple to operate. Ideally, equipment should be portable, lightweight, and rugged.

- Safety--The risk to sampling personnel and others, intrinsic safety of instrumentation, and safety equipment required for conducting the sampling should be carefully evaluated.

3.6.3.2 Sample Locations and Frequency

Because conditions present in the unit or in the contaminant release will change both temporally and spatially, the design of the monitoring network should be developed accordingly. Spatially, sufficient samples should be collected to adequately define the extent of the contamination. Temporally, the plan should address spreading of the release with time and variation of concentrations due to factors such as changes in unit operations, the environment surrounding the unit, and in the composition of the waste. For example, sampling and supplemental measurements (e.g., wind speed) should be conducted when releases are most likely to be observed, when possible.

Selection of specific sampling locations and times will be site and release-dependent. Three general approaches can be used in selecting specific sampling locations. Selection of a particular approach depends on the level of knowledge regarding the release. Judgmental sampling involves selection of sampling locations based on existing knowledge of the release configuration (e.g., visual evidence or geophysical data). A systematic approach involves taking samples from locations established by a predetermined scheme, such as a line or grid. Such samples can help to establish the boundaries of a contaminated area. Random sampling involves use of a "randomizing scheme," such as a random number table, to select locations within the study area. Random sampling can be useful when contaminant spatial distribution is expected to be highly variable. Regardless of the sampling approach taken, it is recommended that a coordinate (grid) system be established at the site to accurately describe and record sampling locations. As a release investigation progresses, and as more information regarding a release is gathered, the sampling approach may be varied as appropriate. Application of judgmental, systematic, and random sampling are discussed below.

3.6.3.3 Judgmental Sampling

Judgmental sampling is appropriate when specific information exists on the potential configuration of a release. Many releases are likely to fall into this category, since site layout or unit characteristics will often indicate areas of potential contamination. Examples of judgemental sampling include:

- Taking air samples at areas generally downwind of a unit;
- Taking grab samples of surface soils from a drainage channel that receives surface run-off from a known contaminated area; and
- Obtaining soil cores downslope from a known waste burial site.

Judgemental sampling will generally bias the data obtained toward higher contaminant concentrations. For example, samples taken only from areas of suspected contamination would generally be biased toward higher concentrations. In many cases, this approach will suit the needs of the RFI.

3.6.3.4 Systematic or Random Grid Sampling

Systematic or random grid sampling allows for the collection of a set of unbiased samples at the area of concern. These samples can be used for detection of contamination, for calculation of averages (e.g., for characterizing the contents of surface impoundments when it is expected to be fairly homogeneous), and for modeling purposes. The size and shape of the grid should consider site-specific factors. However, some general recommendations can be made for effective grid planning. The following steps are recommended in establishing a grid system:

(1) Choose the study area to be included in the grid. This area should be larger than the suspected extent of contamination, in order to define the full extent of the contaminated area.

(2) Select the shape and spacing of the grid. The shape may vary (e.g., rectangular, triangular or radial), depending on the needs of the investigation. The grid spacing should be based on consideration of the appropriate density of sampling points. For example, an initial sampling effort in an area of widespread, homogeneous contamination may use a 200 foot grid, whereas a search for "hot spots" in a poorly defined contaminated area might require a 50 foot or smaller spacing.

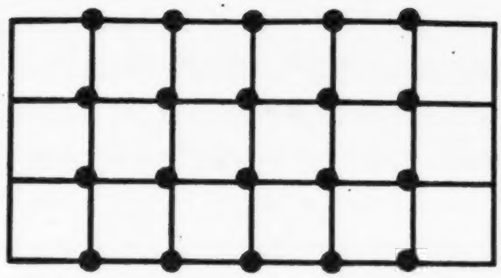
(3) Draw (or overlay) the sampling grid on a plan of the site. To minimize sampling bias, a random number table may be used to choose sampling cells.

(4) Transfer the grid onto the study area by marking grid line intersections with wooden stakes. The exact location of the sample within each grid cell may be chosen systematically (e.g., at each node) or randomly (i.e., anywhere within each cell).

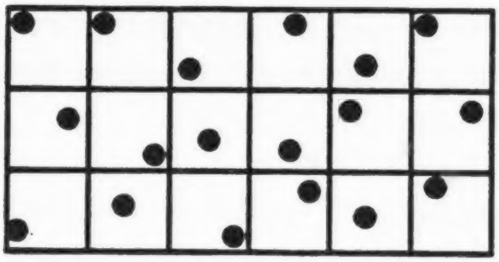
Figure 3-1a shows a systematic grid with samples taken at each node. Random grid sampling produces a sampling distribution such as that shown in Figure 3-1b. A limitation of systematic grid sampling is that if contaminants are distributed in a regular pattern, the sampling points could all lie within the "clean" areas (Figure 3-1c). This possibility should be considered in proposing a sampling approach.

3.6.3.5 Types of Samples

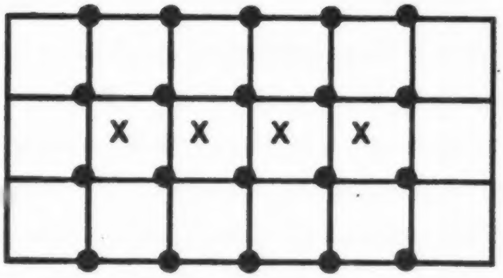
The owner or operator should propose the types of samples to be collected with the monitoring procedures. In general, there are three basic sample types: grab, composite, and integrated.



a) SYSTEMATIC GRID SAMPLING



b) RANDOM GRID SAMPLING



X = BURIED WASTE

c) CASE IN WHICH SYSTEMATIC GRID SAMPLING MISSES WASTES BURIED IN REGULAR PATTERN

FIGURE 3-1. GRID SAMPLING.

- Grab sampling--A grab sample is an individual sample taken at a specific location at a specific time. If a contaminant source or release is known to be fairly constant in composition over a considerable period of time or over substantial distances in all directions, then the sample may serve to represent a longer time period or a larger volume (or both) than the specific point and time at which it was collected.

  When a contaminant source or release is known to vary with time, grab samples collected at suitable intervals and analyzed separately can indicate the magnitude and duration of variations. Sampling intervals should be chosen on the basis of the frequency with which variations may be expected. It may not always be desirable to take samples at equal intervals (e.g., subsurface gas releases are sensitive to seasonal influences). If sample composition is likely to show significant variation with time and space, grab samples from appropriate locations are recommended.

- Composite samples--Composites are combinations of more than one sample collected at various sampling locations and/or different times. Analysis of composites generally yields average values which may not accurately describe the distribution of release concentrations or identify hotspots. Compositing does not reflect peak concentrations and can reduce some concentrations to below detection limits. Composites may, in limited instances, be used to reduce the number of individual grab samples (e.g., when calculating an average value is appropriate). For example, compositing of waste samples from a surface impoundment may be performed to determine an average value over several different locations. Compositing may also be useful in determining the overall extent of a contaminated area, but should not be used as a substitute for characterizing individual constituent concentrations. Therefore, compositing should be highly limited and should always be done in conjunction with an adequate number of grab samples.

- Integrated samples--An integrated sample is typically a continously collected single sample taken to describe a population in which one or more parameters vary either with time or space. An integrated sampling technique can account for such variations by collecting one sample over an extended time period, such that variations can be averaged out over that period. The most common parameter over which sampling periods are integrated is time. Time integrated samples can provide an average of varying concentrations over the period sampled.

  Integrated sampling may be appropriate under limited circumstances. For example, process stream flows often change with variations in the process itself or environmental conditions, such as wind speed. A flow integrated sampling device can collect a sample over a period of time as the sampling rate increases or decreases with the rise and fall of the stream flow. The device automatically biases sample collection towards those periods of high flow, with sampling rates decreasing during low flow periods.

  Integrated samples can particularly useful for air and surface water investigations where continuous changes in environmental conditions can effect constituent concentrations. See Sections 12 and 13 (air and surface water, respectively) for more information.

3.6.4 Analytical Methods and Use of Detection Limits

Analytical methods should be appropriate for the constituents and matrices being sampled. As indicated previously, the EPA publication Test Methods for Evaluating Solid Waste, (EPA/SW-846), should be used as the primary reference for analytical methods. This document contains analytical methods that can be applied to solid, liquid, and gaseous matrices, and also presents detection limits generally associated with these methods. It is important to understand that detection limits can vary significantly depending on the medium (e.g., air, water or soil) and other matrix-specific factors. In addition to SW-846 the following reference provides detection limit information for water and soil matrices:

U.S. EPA. March, 1987. Data Quality Objectives for Remedial Response Activities. Volume 1 (Development Process) and Volume 2 (Example Scenario). Office of Emergency and Remedial Response and Office of Waste Programs Enforcement. EPA 540/G-78/003a. OSWER Directive No. 9335.0-7b. Washington, D.C. 20460.

Detection limits should be stated along with the proposed analytical methods in the RFI Work Plan. Analytical values determined to be at or below the detection limit should be reported numerically (e.g., $\leq$0.1 mg/l).

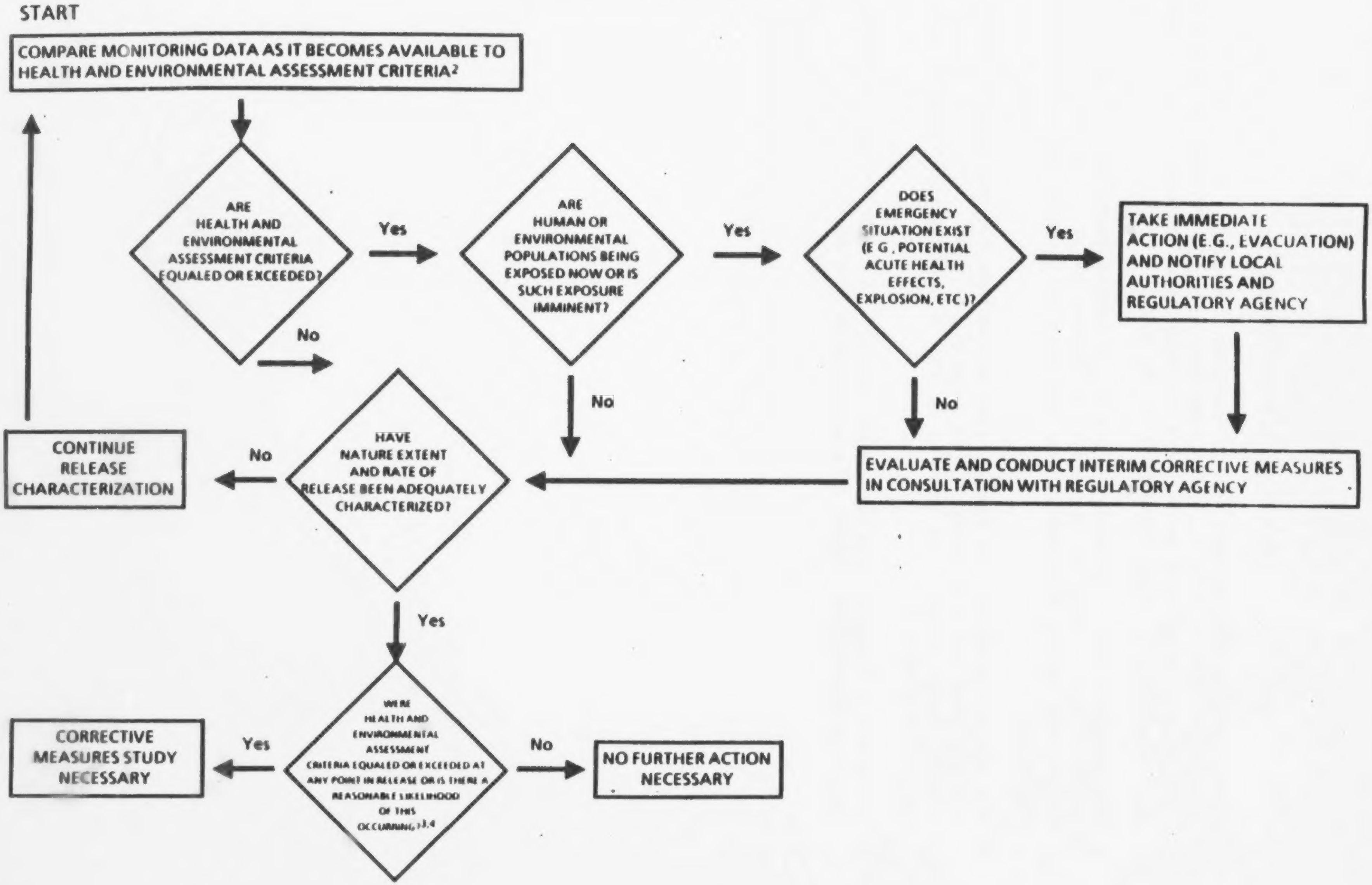
3.7 RFI Decision Points

As monitoring data become available, both within and at the conclusion of discrete investigation phases, it should be reported to the regulatory agency as directed. The regulatory agency will compare the monitoring data to applicable health and environmental criteria to determine the need for (1) interim corrective measures; and (2) a Corrective Measures Study. In addition, the regulatory agency will evaluate the monitoring data with respect to adequacy and completeness to determine the need for any additional monitoring efforts. The health and environmental criteria and a general discussion of how the regulatory agency will apply them are supplied in Section 8. A flow diagram illustrating RFI decision points is provided in Figure 3-2.

Not withstanding the above process, the owner or operator has a continuing responsibility to identify and respond to emergency situations and to define priority situations that may warrant interim corrective measures. For these situations, the owner or operator is directed to obtain and follow the RCRA Contingency Plan requirements under 40 CFR Part 264, Subpart D.

FIGURE 3-2
RFI DECISION POINTS[1]

(See Following Page for Footnotes)


START
COMPARE MONITORING DATA AS IT BECOMES AVAILABLE TO HEALTH AND ENVIRONMENTAL ASSESSMENT CRITERIA[2]
ARE HEALTH AND ENVIRONMENTAL ASSESSMENT CRITERIA EQUALED OR EXCEEDED?
Yes
No
ARE HUMAN OR ENVIRONMENTAL POPULATIONS BEING EXPOSED NOW OR IS SUCH EXPOSURE IMMINENT?
Yes
No
DOES EMERGENCY SITUATION EXIST (E.G., POTENTIAL ACUTE HEALTH EFFECTS, EXPLOSION, ETC.)?
Yes
No
TAKE IMMEDIATE ACTION (E.G., EVACUATION) AND NOTIFY LOCAL AUTHORITIES AND REGULATORY AGENCY
EVALUATE AND CONDUCT INTERIM CORRECTIVE MEASURES IN CONSULTATION WITH REGULATORY AGENCY
HAVE NATURE EXTENT AND RATE OF RELEASE BEEN ADEQUATELY CHARACTERIZED?
No
Yes
CONTINUE RELEASE CHARACTERIZATION
WERE HEALTH AND ENVIRONMENTAL ASSESSMENT CRITERIA EQUALED OR EXCEEDED AT ANY POINT IN RELEASE OR IS THERE A REASONABLE LIKELIHOOD OF THIS OCCURRING?[3,4]
Yes
No
CORRECTIVE MEASURES STUDY NECESSARY
NO FURTHER ACTION NECESSARY

FOOTNOTES FOR FIGURE 3-2

1 Although the health and environmental assessment is conducted by the regulatory agency, the owner or operator has a continuing responsibility to identify and respond to emergency situations and to define priority situations that may warrant interim corrective measures.

2 If sufficient monitoring data indicate that a release identified as "suspected" by the RFA has actually not occurred, no further action is necessary unless the regulatory agency determines that the occurrence of a release is or may be iminent.

3 For the air medium, the health and environmental assessment criteria are applied at receptor locations at and beyond the facility boundary. For all other media, these criteria are applied at the unit or waste management area boundary and beyond.

4 A Corrective Measures Study or interim corrective measures may still be required based on qualitative criteria. (See Section 8 for discussion).

SECTION 4

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

4.1 Overview

Quality assurance (QA) is a management system for ensuring that all information, data, and decisions resulting from the investigation are technically sound, and properly documented. Quality control (QC) is the functional mechanism through which quality assurance achieves its goals. Quality control programs, for example, define the frequency and methods of checks, audits, and reviews necessary to identify problems and dictate corrective action to resolve these problems, thus ensuring high quality data. Thus, a quality assurance and quality control program pertains to all data collection, evaluation, and review activities which are part of the RFI.

Data generated during the RFI will provide the basis for decisions on corrective measures; therefore, the data should present a valid characterization of the situation. Utilization of erroneous or poor quality data in reporting RFI results may lead to unnecessary repetition of sampling and analysis or, more importantly, faulty decisions based on poor results. The owner or operator should develop adequate quality assurance/quality control (QA/QC) procedures for the RFI. Implementation of these procedures will allow the owner or operator to monitor and document the quality of the data gathered.

The next portion of this section (4.2) describes the general design of a QA/QC program. The following portions of this section (Section 4.3 and 4.4) outline and describe important QA/QC considerations that should be accounted for in the performance of sampling and analysis.

Section 4 is not intended to constitute a complete guide to constructing quality assurance project plans or quality control programs. EPA has established, through the issuance of various documents, guidance describing the development and implementation of QA/QC programs that can be used to design effective RFI QA/QC procedures. The final portion of this section (Section 4.5) presents references that provides additional guidance in constructing appropriate QA/QC procedures for the RFI.

When selecting field personnel and analytical services to perform any RFI activity, the owner or operator is encouraged to evaluate available QA/QC programs and procedures against the information and references provided in this section. Participation in internal and/or external (e.g., Federal or State) laboratory validation/certification programs may be particularly important in selecting laboratory services.

Case Study No. 26 in Volume IV (Case Study Examples) provides an example of a effective QA/QC program.

4.2 QA/QC Program Design

The initial step for any sampling or analytical work should be to strictly define the program goals. Once these goals have been defined, a program is designed to meet them. QA and QC measures are used to monitor the program and to ensure that all data generated are suitable for their intended use. The responsibility of ensuring that the QA/QC measures are properly employed should be assigned to a knowledgeable person (i.e., a QA/QC specialist) who is not directly involved in the sampling or analysis.

One approach that has been found to provide a useful structure for a QA/QC program is the preparation of both general program plans and project-specific QA/QC plans. The program plan sets up basic policies, including QA/QC, and may include standard operating procedures (SOP's) for specific methods. The program plan serves as an operational charter for defining purposes, organizations, and operating principles. Thus, it is an orderly assemblage of management policies, objectives, principles, and general procedures describing a plan for producing data of known and acceptable quality. The elements of a program plan and its preparation are described in the following reference:

> U.S. EPA. September 20, 1980. Guidelines and Specifications for Preparing Quality Assurance Program Plans. Office of Monitoring Systems and Quality Assurance. EPA/QAMS-004/80. NTIS PB83-219667. Washington, D.C. 20460.

Project-specific QA/QC plans differ from program plans in that specific details of a particular sampling/analysis program are addressed. For example, a program plan might state that all equipment will be calibrated according to a specific protocol given in written SOP's, while a project plan would state that a particular protocol will be used to calibrate the equipment for a specific set of analyses that have been defined in the plan. The project plan draws on the program plan or its basic structure and applies this management approach to specific determinations. An organization or laboratory would have only one quality assurance program plan, but would have a quality assurance project plan for each of its projects. The elements of a project plan and it's preparation, presented in Table 4-1, are described in detail in the following reference:

> U.S. EPA. December 29, 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. Office of Monitoring Systems and Quality Assurance. EPA/QAMS-005/80. NTIS PB83-170514. Washington, D.C. 20460.

4.3 Important Considerations for a QA/QC Program

The use of qualified personnel for conducting various portions of the RFI is of paramount importance to an effective QA/QC program. This pertains not only to qualified QA/QC specialists, but also to specialists in other fields, including hydrogeologists, air quality specialists, soil scientists, analytical chemists and other scientific and technical disciplines. The owner or operator should ensure that qualified specialists, primarily individuals with the proper education, training, and experience, including licensed or certified professionals, are directing and performing the various RFI activities. The same general principles would apply to selection of contractors and/or outside laboratories.

TABLE 4-1
ESSENTIAL ELEMENTS OF A QA PROJECT PLAN

1. Title Page
2. Table of Contents
3. Project Description
4. Project Organization and Responsibility
5. QA Objectives
6. Sampling Procedures
7. Sample Custody
8. Calibration Procedures and Frequency
9. Analytical Procedures
10. Data Reduction, Validation, and Reporting
11. Internal Quality Control Checks
12. Performance and System Audits
13. Preventive Maintenance
14. Specific Routine Procedures Used to Assess Data Precision, Accuracy, and Completeness
15. Corrective Action
16. Quality Assurance Reports to Management

4.3.1 Selection of Field Investigation Teams

The owner or operator should consider the following factors when selecting any field investigation team:

- Level of expertise and/or training required (e.g., experience, references);
- Available manpower; and
- Time and equipment constraints.

4.3.2 Laboratory Selection

The owner or operator should consider the following factors when selecting a laboratory:

- Capabilities (facilities, personnel, instrumentation), including:
    - Participation in interlaboratory studies (e.g., U.S. EPA or other Federal or State agency sponsored analytical programs);
    - Certifications (e.g., Federal or State);
    - References (e.g., other clients); and
    - Experience (RCRA and other environmentally related projects).
- Service:
    - Turnaround time; and
    - Technical Input (e.g., recommendations on analytical procedures).

The owner or operator is encouraged to gather pertinent laboratory selection information prior to extensive definition of analytical requirements under the RFI. A request may be made to a laboratory to provide a qualifications package that should address the points listed above. Once the owner or operator has reviewed the various laboratory qualifications, further specific discussions with the laboratory or laboratories should take place. In addition, more than one laboratory should be considered. For large-scale investigations, selection of one laboratory as a primary candidate and one or two laboratories as fall-back candidates should be considered. The quality of the laboratory service provided is dependent upon various factors. The owner or operator should be able to control the quality of the information (e.g., samples) provided to the laboratory. It is extremely important that the owner or operator communicate to the laboratory all of the requirements attendant to the RFI. This includes the identification of the number of samples and their matrices, sampling schedule, parameters and constituents (analytes) of interest, required analytical methodologies, detection limits, holding times, deliverables, level of QA/QC, and required turnaround of analytical results.

4.3.3 Important Factors to Address

A major element in release characterization is to define the QA/QC measures that will be followed to ensure the validity of the data generated during the investigation. These measures should ensure that all data generated are suitable for their intended use. QA/QC procedures should address the following factors:

(1) The intended use(s) for the data, and the necessary level of precision and accuracy for these intended uses (See Section 4.4.1).

(2) Procedures for representative sampling including:

- Selecting appropriate sampling locations, depths, etc.;
- Providing a sufficient number of samples and sampling sites;
- Obtaining all necessary ancillary data;
- Determining conditions (e.g., weather) under which sampling should be conducted;

- Determining which media are to be sampled (e.g., ground water, air, soil, sediment, etc.);
- Determining which constituents are to be measured;
- Selecting appropriate sample containers;
- Selecting the frequency of sampling and duration of the sampling period;
- Selecting the types of samples (e.g., composites and grabs) to be collected;
- Sample preservation; and
- Sample chain-of-custody.

(3) Documentation of field sampling operations and procedures including:

- Documentation of procedures for preparation of reagents or supplies that become an integral part of the sample (e.g., filters, and adsorbing reagents);
- Procedures and forms for recording the exact location and specific considerations associated with sample acquisition;
- Documentation of specific sample preservation methods;
- Calibration of field devices;
- Collection of replicate samples;
- Submission of field blanks, where appropriate;
- Potential interferences present at the facility;

- Construction materials and techniques associated with monitoring wells, piezometers, and other monitoring equipment;
- Field equipment listing and sample containers;
- Sampling order; and
- Decontamination procedures.

(4) Analytical procedures including:

- Appropriate analytical methods;
- Appropriate sample storage;
- Appropriate sample preparation methods;
- Appropriate calibration procedures; and
- Data management (e.g., review, reporting, and recordkeeping).

(5) Planning for the inclusion of proper and sufficient QA/QC activities, including the use of QC samples throughout all phases of the study is necessary to ensure that the quality of the sampling and analytical data will meet the objectives of the RFI.

The factors and considerations described above are important for any environmental monitoring and measurement project. If these factors are adequately addressed (i.e., appropriate procedures are developed, tasks are assigned to qualified personnel, and sufficient QA/QC steps are employed), the goals of the RFI should be met. If the QA/QC procedures are sound, problems will be detected early, thus enabling the appropriate corrective actions to be taken.

[Note that the term "corrective action," in the context of a QA/QC program pertains to actions taken as a result of problems (e.g., sample contamination) uncovered by an effective QA/QC program. This should not be confused with the corrective measures that may be applied as a result of the RFI. Corrective actions as a result of QA/QC are discussed in Section 4.4.10.]

4.4 QA/QC Objectives and Procedures

The following describes the general components of QA/QC objectives and procedures. Specific references regarding recommended procedures are presented in Section 4.5.

4.4.1 Data Quality and Use

Throughout the RFI process, it is important that the owner or operator keep in mind the eventual use to which the data will be put; that is, comparison of data to health and environmental criteria to determine whether some form of corrective measure may be necessary for correcting the release. Therefore, the data collected during the investigation needs to be of sufficient quality to support decisions regarding whether interim corrective measures or a Corrective Measures Study are necessary.

Qualitative or quantitative statements that outline the decision-making process and specify the quality and quantity of data required to support decisions should be made early in the planning stages of the RFI. These data quality objectives (DQOs) are then used to design sampling and analysis plans and to determine the appropriate level of QA/QC.

The following discussion concerning DQOs is summarized from the following document:

> U.S. EPA. March, 1987. Data Quality Objectives for Remedial Response Activities. Volume 1: Development Process. Volume 2: Example Scenario. EPA 540/G-87/003a. OSWER Directive No. 9335.0-7B. Office of Emergency and Remedial Response and Office of Waste Programs Enforcement. Washington, D.C. 20460.

This document may be reviewed for more detailed information. The Example Scenario (Volume 2) may be particularly helpful in understanding the overall DQO process.

The process of developing DQOs involves first defining the decisions to be made based on the data and the objectives of the investigation. The second step is to define a set of objectives (DQOs) that can then be used to design the sampling and analysis plan, and to determine the appropriate level of quality assurance and control. Ultimately, these DQOs are also used to determine the adequacy of the data in terms of whether it is of sufficient quality and quantity to enable confident decision-making. This process of defining the objectives of the investigation, and designing data-gathering efforts to meet these objectives, should be initiated early on in the investigation.

The criteria used most commonly to specify DQOs and to evaluate available sampling, analytical, and QA/QC options are known collectively as the PARCC (Precision, Accuracy, Representativeness, Completeness, and Comparability) parameters. A brief description of these follows:

- Precision - a measure of the reproducibility of analyses under a given set of conditions.
- Accuracy - a measure of the bias that exists in a measurement system.
- Representativeness - the degree to which sampling data accurately and precisely represent selected characteristics.
- Completeness - a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under "normal" conditions.
- Comparability - the degree of confidence with which one data set can be compared to another.

When using these parameters to assess data quality, only precision and accuracy can be expressed in purely quantitative terms. The other parameters are best expressed using a mixture of quantitative and qualitative terms. All of these parameters are interrelated in terms of overall data quality and they may be difficult to evaluate separately due to these interrelationships. The relative significance of each of the parameters depends on the type and intended use of the data being collected. Each of the individual parameters is addressed in further detail below.

Precision is a measure of the scatter of a group of measurements made at the same specified conditions about their average. Values calculated should demonstrate the reproducibility of the measurement process. The determination of precision in relation to the RFI deals primarily with sampling and analytical procedures. The sample standard deviation and sample coefficient of variation are commonly used as indices of precision. The smaller the standard deviation and coefficient of variation, the better the precision.

Precision is stated in the units of measurement or as a percentage of the measurement average, as a plus and minus spread around the average measured value. There are many sources of variation or error within any measurement system. Depending on the nature of the investigation, variation or error may be introduced at various stages. Examples of these are sample collection, handling, shipping, storage, preparation, and analysis. When summarizing precision determinations, the component or components of the measurement system that are included should be noted. The stage at which a replicate is placed within the measurement system, for example, generally dictates the components that affect the precision determination.

Accuracy is defined as the agreement of a measurement with an accepted reference or true value. This is normally expressed as the difference between measured and reference or true values or the difference as a percentage of the reference or true value. It may also be expressed as a ratio of the measurement to the true value. Accuracy is a measurement of the systematic bias.

The determination of accuracy or bias within the measurement system is generally accomplished through the analysis of the neat sample (e.g., distilled water as opposed to pond or local water) and the analysis of the sample spiked at a known concentration utilizing a standard reference material. As in the case of the precision determination, the point at which the sample is spiked determines which components of the measurement system have an effect upon the accuracy of the analysis. The three sample spiking points are: sample acquisition (field matrix spike); preparation (lab matrix spike); and analysis (analysis matrix spike). The field matrix spike provides a best-case estimate of bias based on recovery. It includes matrix effects associated with sample preservation, shipping, preparation, and analysis. The lab matrix spike provides an estimate of recovery incorporating matrix effects associated with sample preparation and analysis only. The analysis matrix spike provides an indication of matrix effects associated with the analysis process only. In addition to the above sample spiking points, the analysis of a known concentration of a standard reference material into the appropriate method solvent (e.g., deionized water, methanol, 2 percent nitric acid, etc.) provides an indication of the accuracy of the analytical system calibration.

Completeness is defined as the measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under "normal" conditions. The completeness goals should be identified, to the extent possible, at the beginning of the RFI to ensure that sufficient valid data are collected to meet the RFI objectives and to provide a measurement whereby the progress of the RFI may be monitored during data collection.

QA/QC procedures may benefit through tabular presentations of the precision, accuracy, and completeness goals for the work performed under the RFI.

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. QA/QC procedures should address all data gathering with regards to representativeness. All RFI data compilation should reflect as precisely and as accurately as possible the conditions that existed at the time of measurement. Examples of factors that should be considered include:

- Environmental conditions at the time of sampling;
- Fit of the modeling or other estimation techniques to the event(s);
- Appropriateness of site file information versus release conditions;
- Appropriateness of sampling and analytical methodologies;

- Number of sampling points;

- Representativeness of selected media; and

- Representativeness of selected analytical parameters.

Comparability is defined as an expression of the confidence with which one data set can be compared to another. In terms of the RFI, comparability may be applied to:

- RFI data generated by the owner or operator over a specific time period;

- Data generated by an outside laboratory over a specific time period;

- RFI data generated by an outside laboratory versus data generated by the owner or operator; and

- Data generated by more than one outside laboratory.

The utilization of standard methodologies for the various data generation categories (e.g., sampling, analysis, geological, and meteorological) should ensure data comparability. The owner or operator should take the appropriate measures to ensure the comparability of the data compiled under the RFI.

The PARCC parameters are indicators of data quality. Ideally, the end use of the measurement data should define the PARCC parameters that are necessary to satisfy that end use. Ideally, numerical precision, accuracy, and completeness goals should be established to aid in selecting the measurement methods to be used. However, RFI work may not fit this ideal situation. RFI sites are likely to differ substantially from each other and information on overall measurements (e.g., sampling and analysis) may be limited such that it may not be practical to initially set meaningful PARCC goals. In such cases, the historical precision and accuracy achieved by different sampling and analytical techniques should be reviewed to aid in selection of the most appropriate technique. Only those techniques that have been adequately evaluated (e.g., precision and accuracy studies), and which therefore have a documented history of acceptable performance, should be proposed for use.

Precision and accuracy statements and detection limit information for analytical methods can be found in the DQO document referenced earlier in this section, as well as the following reference:

> U.S. EPA. November, 1986. Test Methods for Evaluating Solid Wastes. EPA/SW-846. GPO No. 955-001-00000-1. Office of Solid Waste. Washington, D.C. 20460.

Each of the PARCC parameters should be considered in evaluating sampling and analysis options. To the extent possible, they should be defined as goals to be achieved by the data collection program. It should be recognized, however, that DQOs can be developed for RFI work without strictly defined PARCC goals.

Whenever measurement data are reviewed, the PARCC parameters should be included in the review. Precision and accuracy data may be expressed in several ways and are best evaluated by an analytical chemist or a statistician. The data reviewer should keep the levels of concern (health and environmental criteria) and the end use of the data in mind when reviewing precision and accuracy information. In some cases, even data of poor precision and/or accuracy may be useful. For example, if all the results are far above a level of concern, the precision and accuracy are much less important. However, close to the level of concern, precision and accuracy are much more important and should be carefully reviewed. If results have very good precision but poor accuracy, correcting the reported results using the percent recovery or percent bias data may be acceptable.

4.4.2 Sampling Procedures

To ensure that the sample collection will provide high quality and representative data, the owner or operator is advised to carefully select appropriate sampling procedures that will meet the objectives of the investigation. Some of the factors to consider in choosing the best sampling methodologies include the following:

- Physical and chemical properties of the medium to be sampled;
- Relative and absolute concentrations of analytes of concern;
- Relative importance of various analytes to RFI objectives;
- Method performance characteristics;
- Potential interferences present at the site; and
- Time resolution requirements.

QA/QC procedures relevant to sampling activities should also be formulated and followed during any site environmental characterization. These procedures should include a description of the techniques to be utilized in performing tasks such as well drilling, stratigraphic analysis, meteorological measurements, and surface water flow measurements. More information can be found in the references identified in Section 4.5, and in the media-specific sections (Sections 9 through 13).

4.4.3 Sample Custody

An essential part of any program that requires sampling and analysis is ensuring the sample integrity from collection to data reporting. This includes the ability to trace the possession and handling of samples from the time of collection through analysis and final disposition. The documentation of the history of the sample is referred to as chain-of-custody.

Chain-of-custody procedures should identify the components that will be utilized for all sampling and analysis under the RFI, including a transfer in custody and how the chain-of-custody procedures and documents will effectively record that transfer. The following sample custody procedures should be addressed:

(1) Field Sampling Operations:

- Documentation of procedures for preparation of reagents or supplies that become an integral part of the sample (e.g., filters and adsorbing reagents);

- Procedures and forms for recording the exact location and specific considerations associated with sample acquisition;

- Documentation of specific sample preservation methods;

- Pre-prepared sample labels containing all information necessary for effective sample tracking; and

- Standardized field tracking reporting forms to establish sample custody in the field prior to shipment.

(2) Laboratory Operations:

- Identification of a responsible party to act as sample custodian at the laboratory facility authorized to sign for incoming field samples, obtain documents of shipment, and verify the data entered onto the sample custody records;

- Provision for a laboratory sample custody log consisting of serially numbered standard lab-tracking report sheets; and

- Specification of laboratory sample custody procedures for sample handling, storage, and dispersement for analysis.

4.4.4 Calibration Procedures

Another important consideration in any environmental measurement is the calibration of the measurement system. An improperly and/or infrequently calibrated system may have a serious negative impact on the precision and accuracy of the determinations. The result will be erroneous data and the need to repeat the measurements. The calibration procedures utilized should therefore be defined. Points that should be addressed include:

- For each measurement parameter, including all contaminant measurement systems, reference the applicable standard operating procedure or provide a written description of the calibration procedure(s) to be used;

- List the frequency planned for recalibration and/or the criteria utilized to dictate the frequency of recalibration; and

- List the calibration standards to be used and their source(s), including traceability procedures.

4.4.5 Analytical Procedures

The owner or operator should select analytical procedures that will meet the objectives of the RFI. Factors to consider in choosing appropriate analytical methodologies include:

- Scope and application of the procedure;

- Sample matrix;

- Potential interferences;

- Precision and accuracy of the methodology; and

- Method detection limits.

EPA-approved methodologies, such as those identified in the 3rd edition of Test Methods for Evaluating Solid Wastes (EPA/SW-846) or equivalent, should be utilized when available.

For each measurement parameter, including all contaminant measurement systems, the owner or operator should reference the standard operating procedure or provide a written description of the analytical procedure(s) to be used in support of the RFI. If any method modifications are anticipated due to the nature of the sample(s) being investigated, these modifications should be explicitly defined.

An important factor to consider in any analytical procedure is the holding time. Samples have a limited shelf life. Analysis should occur within the time specified by the method. This is especially important for organic contaminants. For example, volatile organic compound analysis should occur within 2 weeks of sampling. Acceptable sample holding times for all classes of Appendix VIII constituents are discussed in Test Methods for Evaluating Solid Waste (EPA/SW-846).

4.4.6 Data Reduction, Validation, and Reporting

This portion of the QA/QC procedures applies to all measurements performed in support of the RFI. The owner or operator should identify the data reduction scheme planned on collected data and include all equations used to calculate the concentration or value of the measured parameter and reporting units.

Data validation is the process of reviewing data and accepting or rejecting it on the basis of sound criteria. The validation methods may differ for various measurements but the chosen validation criteria must be appropriate to each type of data and the purpose of the measurement. Records of all data should be maintained, even those judged to be "outlying" or spurious values. Personnel assigned the responsibility of data validation should have sufficient knowledge of the particular measurement system to identify questionable values.

The owner or operator should identify the principal criteria that will be applied to validate data integrity during collection and reporting. In addition, the methods that will be utilized to identify and treat outliers should be addressed. The validation process should include mechanisms whereby data reduction is verified. In the case of computerized data reduction, this may include subjecting a surrogate data set to reduction by the software to ensure that valid results are produced.

4.4.7 Internal Quality Control Checks

Quality control checks are performed to ensure the collection of representative and valid data. Internal quality control refers to all data compilation and contaminant measurements. Quality control checks are the mechanisms whereby the components of quality assurance objectives are monitored. Examples of items to be considered are as follows:

(1) Field Activities:

- Standardized checklists and field notebooks;
- Verification of checklist information by an independent person;
- Strict adherence to chain-of-custody procedures;
- Calibration of field devices;
- Collection of replicate samples; and
- Submission of field blanks, where appropriate.

(2) Analytical Activities:

- Method blank(s);
- Laboratory control sample(s);
- Calibration check sample(s);
- Replicate sample(s);
- Matrix-spiked sample(s);
- "Blind" quality control sample(s);
- Control charts;
- Surrogate samples;
- Zero and span gases; and

- Reagent quality control checks.

The owner or operator should consider those checks that will meet the quality assurance objectives of the RFI. In addition, the owner or operator should present, in tabular format, the frequency with which each control check will be used.

4.4.8 Performance and Systems Audits

A systems audit is a qualitative evaluation of all components of the measurement systems to determine their proper selection and use. This audit includes a careful review of all data-gathering activities and their attendant quality control procedures. Systems audits are normally performed prior to or shortly after systems are operational. However, such audits should be performed at sufficiently regular intervals during the lifetime of the RFI or continuing operation. Systems audits should be conducted by an individual who is technically knowledgeable about the operation(s) under review and who is independent of any other contribution to the RFI. The primary objective of the systems audit is to ensure that the QA/QC procedures are being adhered to.

After systems are operational and generating data, performance audits are conducted periodically to determine the accuracy of the total measurement system(s) or component parts thereof. Performance audits are quantitative evaluations of the measurement system(s). QA/QC procedures should include a schedule for conducting performance audits for each measurement parameter where all measurement systems are included. Examples of performance auditing mechanisms for analytical activities would be the inclusion of "blind" samples into the normal sample flow, an analyst performing the analysis of a sample previously analyzed by another analyst, and the results of any appropriate interlaboratory study samples analyzed during the term of the RFI. Performance audit checks relative to data handling operations might be the insertion of erroneous parameters into field records. This should trigger the validation procedures by entering unreasonable combinations of responses.

4.4.9 Preventative Maintenance

Preventative maintenance schedules assure the maximum amount of active time for analytical instrumentation, field devices and instrumentation, and computer hardware over the course of the RFI program. The following types of preventative maintenance should be considered:

- A schedule of important preventative maintenance tasks that must be carried out to minimize downtime of all measurement systems; and
- A list of any critical spare parts that should be on hand to minimize downtime.

4.4.10 Corrective Action for QA/QC Problems

Corrective actions are those measures taken to rectify a measurement system that is out of control. [Note that the term "Corrective Action," as used in this section, is a common QA/QC term applied to problem-solving activities. It should not be confused with the RCRA Corrective Action Program.] Corrective action may be initiated by any person performing work in support of the RFI at any time. As an example, an analyst should be familiar with the precision and accuracy of the analysis that he is performing. If the results of the analysis are not within the anticipated limits, there are corrective actions that should be initiated by the analyst. There are, however, other checks within the measurement system that only the person assigned QA/QC responsibilities would be in a suitable position to evaluate and take action upon if required. A "blind" sample inserted in the normal sample flow would be an example of such a check.

The corrective action procedures to be utilized in the accomplishment of the RFI objectives should be contained in the QA/QC procedures and should include the following elements:

- The predetermined limits for data acceptability beyond which corrective action is required; and

- For each measurement system, the identity of the responsible individual for initiating the corrective action and also the individual responsible for approving the corrective action, if necessary.

In addition to the routine corrective actions taken by all personnel contributing to the RFI, performance and systems audits may result in the necessity of more formal corrective action.

4.4.11 Quality Assurance Reports to Management

Another important aspect of the QA/QC program is the communication between the QA/QC organization and the management organization. Regular appraisal by management of the quality aspects related to the ongoing RFI data gathering efforts provides the mechanism whereby the established objectives may be met.

QA/QC procedures should provide details relating to the schedule, information to be provided, and the mechanism for reporting to management. Reports to management should include:

- Periodic assessment of measurement data accuracy, precision, and completeness;

- Results of performance audits;

- Results of system audits;

- Significant QA/QC problems and recommended solutions; and

- Resolutions of previously stated problems.

The individual(s) responsible for preparing the periodic reports should be identified. These reports should contain a separate QA/QC section that summarizes data quality information contained in the periodic reports.

4.5 References

Following is a list of the major references, including EPA guidances, that are recommended for use in designing effective QA/QC programs for RCRA Facility Investigations:

U.S. EPA. September 20, 1980. Guidelines and Specifications for Preparing Quality Assurance Program Plans. Office of Monitoring Systems and Quality Assurance. QAMS-004/80. NTIS PB83-219667. Washington, D.C. 20460.

U.S. EPA. December 29, 1980. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. Office of Monitoring Systems and Quality Assurance. QAMS-005/80. NTIS PB83-170514. Washington, D.C. 20460.

U.S. EPA. September, 1986. Test Methods for Evaluating Solid Wastes. 3rd Edition. Office of Solid Waste. EPA/SW-846. GPO No. 955-001-00000-1. Washington, D.C. 20460.

U.S. EPA. 1987. Compendium of Field Operations Methods. OSWER Directive No. 9355.0-14. Office of Emergency and Remedial Response. Washington, D.C. 20460.

U.S. EPA. July, 1981. RCRA Inspection Manual. Office of Solid Waste. Washington, D.C. 20460.

U.S. EPA. June, 1985. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response. NTIS PB 85-238616. Washington, D.C. 20460.

U.S. EPA. May, 1984. Soil Sampling Quality Assurance Users Guide. EPA 600/4-84-043. NTIS PB84-198621. Washington, D.C. 20460.

U.S. EPA. 1985. Sediment Quality Assurance Users Guide. EPA 600/4-85-048. NTIS PB85-233542. Washington, D.C. 20460.

U.S. EPA. March, 1987. Data Quality Objectives for Remedial Response Activities. Volume 1: Development Process. Volume 2: Example Scenario. EPA 540/G-87/003a. OSWER Directive No. 9335.0-7B. Office of Emergency and Remedial Response and Office of Waste Programs Enforcement. Washington, D.C. 20460.

SECTION 5

DATA MANAGEMENT AND PRESENTATION

5.1 Data Management

Release characterization studies may produce significant amounts of data, including results of chemical, physical or biological analyses. This may involve analyses of many constituents, in different media, at various sampling locations, and at different points in time. Data management procedures should be established to effectively process these data such that relevant data descriptions (e.g., sample numbers, locations, procedures, methods, and analysts) are readily accessible and accurately maintained.

In order to insure effective data management, the owner or operator should develop and implement a data management plan to document and track investigation data and results. This plan should address data and report processing procedures, project file requirements and all project-related progress reporting procedures and documents. The plan should also provide the format(s) to be used to present the data, including data reduction.

Data presentation, reduction and reporting are discussed in Sections 5.2, 5.3, and 5.4 respectively.

5.2 Data Presentation

RFI data should be arranged and presented in a clear and logical format. Tabular, graphical, and other visual displays (e.g., contaminant isopleth maps) are essential for organizing and evaluating such data. Tables and graphs are not only useful for expressing results, but are also necessary for decision-making during the investigation. For example, a display of analytical results for each sampling location superimposed on a map of the site is helpful in identifying data gaps and in selecting future sampling locations. Graphs of concentrations of individual constituents plotted against the distance from the source can help to identify patterns, which can be used to design further monitoring efforts.

Various tabular and graphical methods are available for data presentation, as illustrated in Table 5-1. The particular methods that are most applicable to the RFI may vary with the type of unit, the type of data, the medium under consideration, and other factors. The owner or operator should propose methods in the RFI Work Plan that will best illustrate the patterns in the data.

Often, certain types of data, such as stratigraphy and sampling location coordinates are more effectively displayed in graphical form. Such data may be presented in tabular form but should also be transformed into graphical presentations. For example, stratigraphy might be effectively illustrated on a 2-dimensional (or possibly 3-dimensional) cross-sectional map. 3-dimensional data presentation is particularly relevant to the RFI, as 3-dimensional characterization is generally required to adequately characterize the nature, extent, and rate of release migration.

Sampling locations may be effectively illustrated on a topographic map, a s hown in Figure 5-1. Topographic maps and the regulatory requirements for their preparation (40 CFR Part 270.14(b)) are also discussed in Appendix A. Table 5-2 provides some recommended data presentation methods. In addition, many of the Case Studies presented in Volume IV illustrate effective data presentation techniques. Case Study No. 25 is of particular relevance to data presentation techniques. Specific data presentation techniques are discussed below.

5.2.1 Tables

Tabular presentations of both raw and sorted data are useful means of data presentation. These are discussed below.

5.2.1.1 Listed (Raw) Data

Simple lists of data alone are not adequate to fully illustrate trends or patterns resulting from a contaminant release. However, such lists serve as a good starting point for other presentation formats. These lists are also valuable for sample

Table 5-1

Uses of Tables and Graphics in a RFI

Tabular Displays

1. Display site information and measurements
    - Water table elevations
    - Sampling location coordinates
    - Precipitation and temperature data
    - Lists of site fauna and flora species

2. Display analytical data
    - List of constituents of concern and other monitoring parameters with associated analytical measurements
    - Display sorted results (e.g., by medium, sampling date, soil type)
    - Compare study and background area data
    - Report input data, boundary conditions, and output values from mathematical modeling

Graphical Displays

1. Display site features
    - Layout and topography (equivalent to required RCRA permit application map)
    - Sampling locations and sampling grids
    - Boundaries of sampling area
    - Stratigraphy and water table elevations (profile, transect, or fence diagram)
    - Potentiometric contour map of ground water
    - Ground-water flow net
    - Population plot and/or local residential map
    - Features affecting inter-media transport

2. Illustrate the extent of contamination
    - Geographical (areal) extent of contamination
    - Vertical distribution of contaminant(s)
    - Contamination values, averages, or maxima at sampling locations

3. Demonstrate patterns and trends in the data
    - Change in concentration with distance from the source
    - Change in concentration with time
    - Display estimates of future contaminant transport derived from modeling

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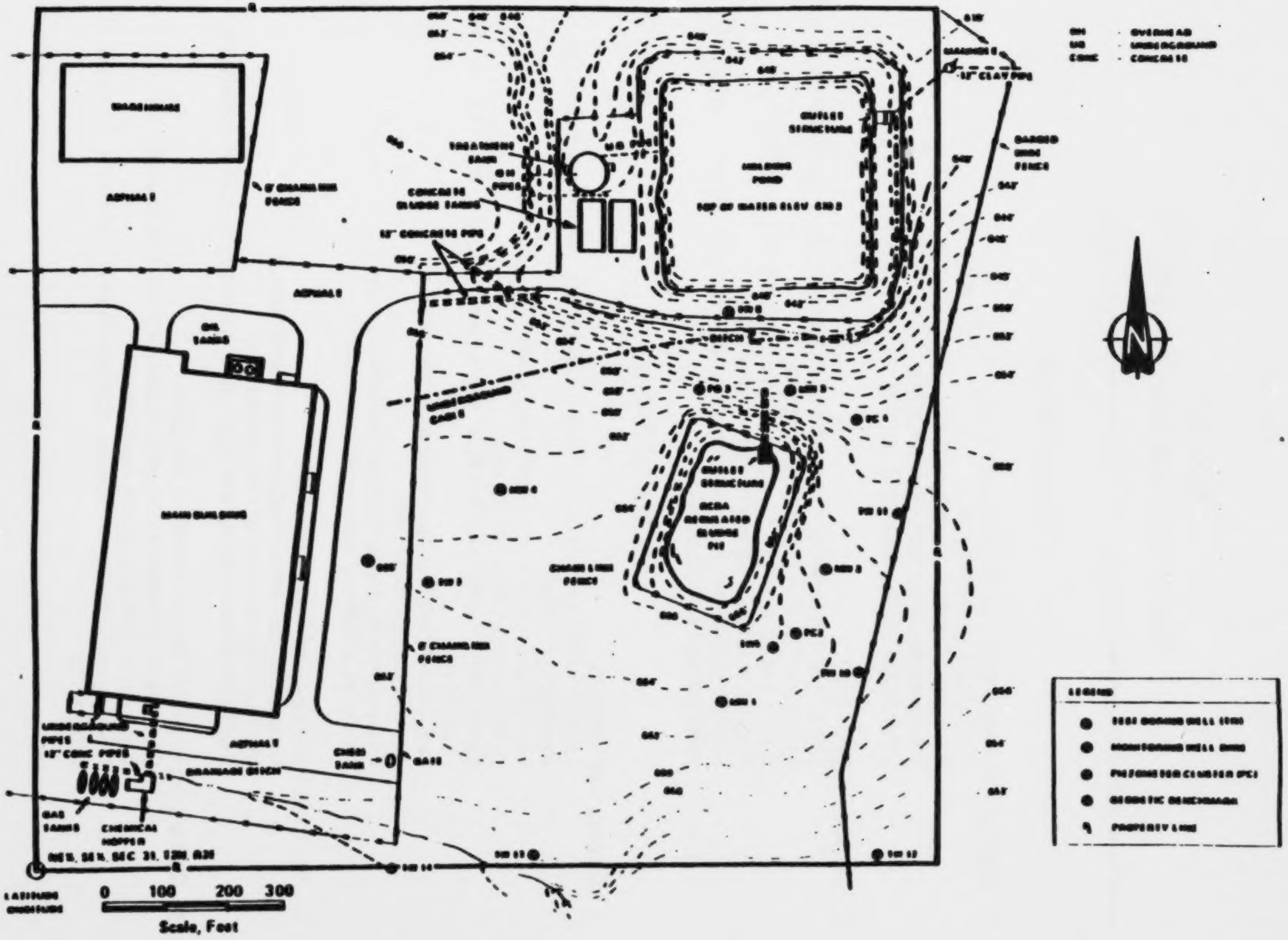

N
0
100
200
300
Scale, Feet

Figure 5-1. Topographic Map wing Sampling Locations

Table 5-2
Recommended Data Presentation Methods

Tables

- Unsorted (raw) data
- Sorted tables

Graphical Formats and Other Visual Displays

- Bar graphs
- Line graphs
- Area or plan Maps
- Isopleth (contour) plots
- Ground-water flow nets
- Cross-sectional plots, transects, or fence diagrams
- Three-dimensional graphs

validation and auditing purposes. Therefore, such lists are highly recommended for reporting of results during the RFI. Each data record should provide the following information:

- Unique sample code;
- Sampling location and sample type;
- Sampling date;
- Laboratory analysis identification number;
- Property or component measured;
- Result of analysis (e.g., concentration);
- Detection limits; and
- Reporting units.

Analytical data will generally be reduced at the laboratory before it is reported (i.e., the owner or operator does not have to report instrument readings or intermediate calculations, although this information should be maintained for ready access if needed). The owner or operator should report all data to the regulatory agency, including suspected outliers or samples contaminated due to improper collection, preservation, or storage procedures. The rejected data should be marked as such in the data tables, and explanations of rejected data should be presented in footnotes.

In addition to analytical data, the owner or operator may be required to provide sampling logs for all samples obtained during the investigation. Sampling logs are records of procedures used in taking environmental samples, and conditions prevailing at the site during sampling. Information in the log should include:

- Name and address of sampler;

- Purpose of sampling;
- Date and time of sampling;
- Sample type (e.g., soil) and suspected contaminants;
- Sampling location, description, and grid coordinates (including photos);
- Sampling method, sample containers, and preservation (if any);
- Sample weight or volume;
- Number of samples taken;
- Sample identification number(s);
- Amount purged (for ground water);
- Field observations;
- Field measurements made (e.g., pH, temperature);
- Weather conditions; and
- Name and signature of person responsible for observation.

The owner or operator should also describe any unusual conditions encountered during sampling (e.g., difficulties with the sampling equipment, post-sampling contamination, or loss of samples).

5.2.1.2 Sorted Summary Tables

Presentation of results grouped according to data categories is among the simplest format used to display trends or patterns in the data. Examples of categories of data include medium tested, sampling date, sampling location, and constituent or property measured. Table 5-3 shows an example of a sorted table;

Table 5-3

Concentration of Volatile Organic Compounds in Monitoring Well #32

		Concentration (ug/l)			
Date	Sample identification	Methylene chloride	Acetone	Trichloroethylene	Benzene
1/3/82	MW-32-1/3A	20	120	20	30
2/12/82	MW-32-2/12A	≤10	220	NA	≤10
4/24/82	MW-32-4/24A	≤10	140	20	20

NA - Not analyzed.

data are sorted by medium (ground water), sampling date, and constituent measured.

In Table 5-4, the data are sorted by medium, location, depth, and constituent analyzed. Inclusion of the sample identification number allows the reader to cross-reference the data and look up any information not listed in the table.

Preparation of data summary tables can be simplified by use of a computer spreadsheet program. These programs can perform sorting operations, perform simple calculations with the data, and display results in a number of tabular and graphical formats.

5.2.2 Graphical Presentation of Data

Graphical methods of data presentation will often illustrate trends and patterns better than tables. Some graphical formats that are useful for environmental data include bar graphs, line graphs, areal maps, and contour-plots. These graphical methods of data presentation are discussed below.

5.2.2.1 Bar Graphs and Line Graphs

Bar graphs and line graphs may be used to display changes in contaminant concentrations with time, distance from a source, or other variables. For example, Figure 5-2 compares two methods of displaying changes in concentrations over distance. Bar graphs are generally preferable to line graphs in instances where there is not enough information to assume continuity between data points. However, line graphs generally can display more information in a single graph.

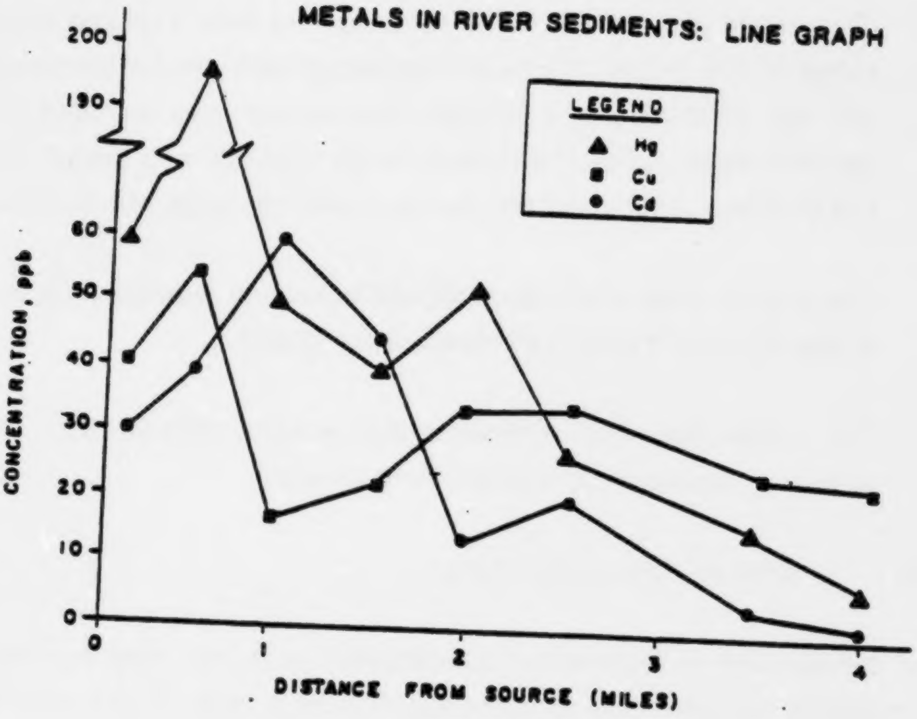
Attention to the following principles of graphing should provide clear and effective line and bar graphs:

- Do not crowd data onto a graph. Plots with more than three or four lines or bar subdivisions become confusing. Different symbols or textures should be used to distinguish each line or bar;

Table 5-4

Soil Analyses: Sampling Date 4/26/85

			Concentration (mg/kg)		
Sample ID	Location	Depth	Lead	Arsenic	Chromium
SB-1	N of lagoon	surface	240	55	1,200
SB-2	N of lagoon	6"	40	15	220
SB-3"	N of lagoon	18	15	15	36
SB-4	SE corner	surface	360	84	5,300
SB-5	SE corner	6"	170	29	430
"SB-6	SE corner	18	22	≤1.0	47



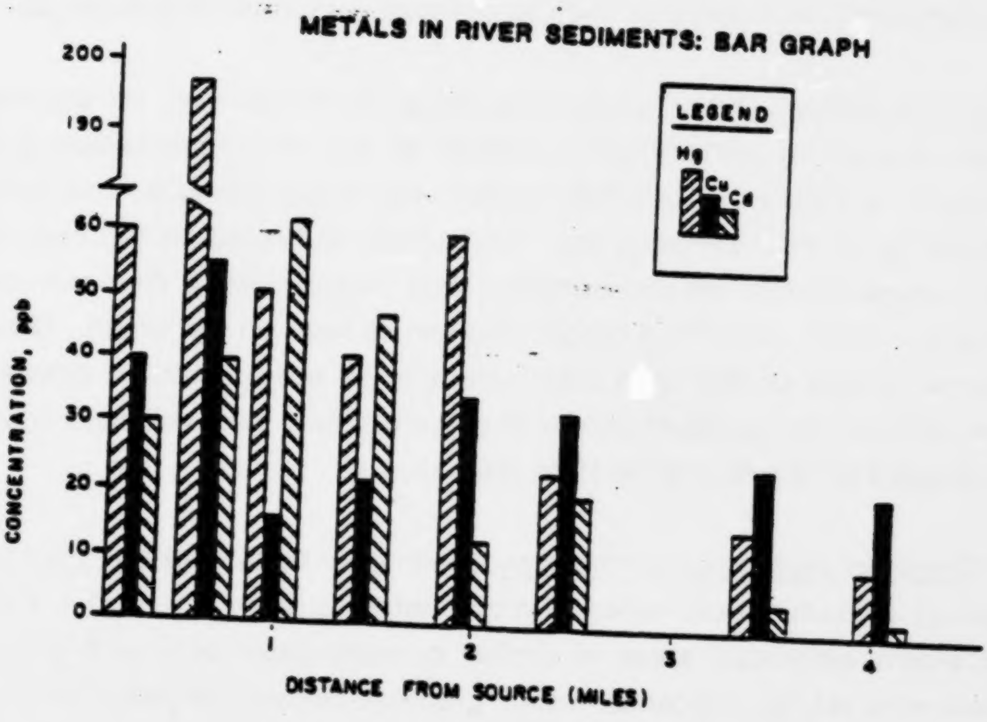


Figure 5-2. Comparison of line and bar graphs

- Choose the scale of the x and y axes so that data is spread out over the full range of the graph. If one or two data points are far outside the range of the rest of the data, a broken line or bar may be used to indicate a discontinuous scale. If the data range exceeds two orders of magnitude, the owner or operator may choose to plot the logarithms of the data;

- The x and y axes of the plot should be clearly labeled with the parameter measured and the units of measurement; and

- The x axis generally represents the independent variable and the y axis generally represents the dependent variable.

5.2.2.2 Area or Plan Views (Maps)

The distribution of hazardous constituents at a site may be represented by superimposing contaminant concentrations over a map of the site. Distributions may be shown by listing individual measurements, or by contour plots of the contaminant concentrations. Individual techniques are discussed below:

Contamination shown at discrete points--In this format, no assumptions are made concerning contamination outside of the immediate sampling area. For example, in Figure 5-3, soil PCB concentrations are shown by the height of the vertical bar at each sampling site. Soil samples indicated on this map were taken from approximately the same depth. Note that one bar is discontinuous so as to bring the lower values to a height that can be seen on the graph. Other possible representations of the same information could use symbols of different shapes, sizes, or colors to represent ranges of concentration. For example, a triangle might represent 0 to 10 ppb; a circle 10 to 100 ppb, etc.

Display of average concentrations--Shadings or textures can be used to represent average contamination concentrations within smaller areas at a site. Shading represents estimated areas of similar concentration only and should not be interpreted as implying concentration gradients between adjacent points.

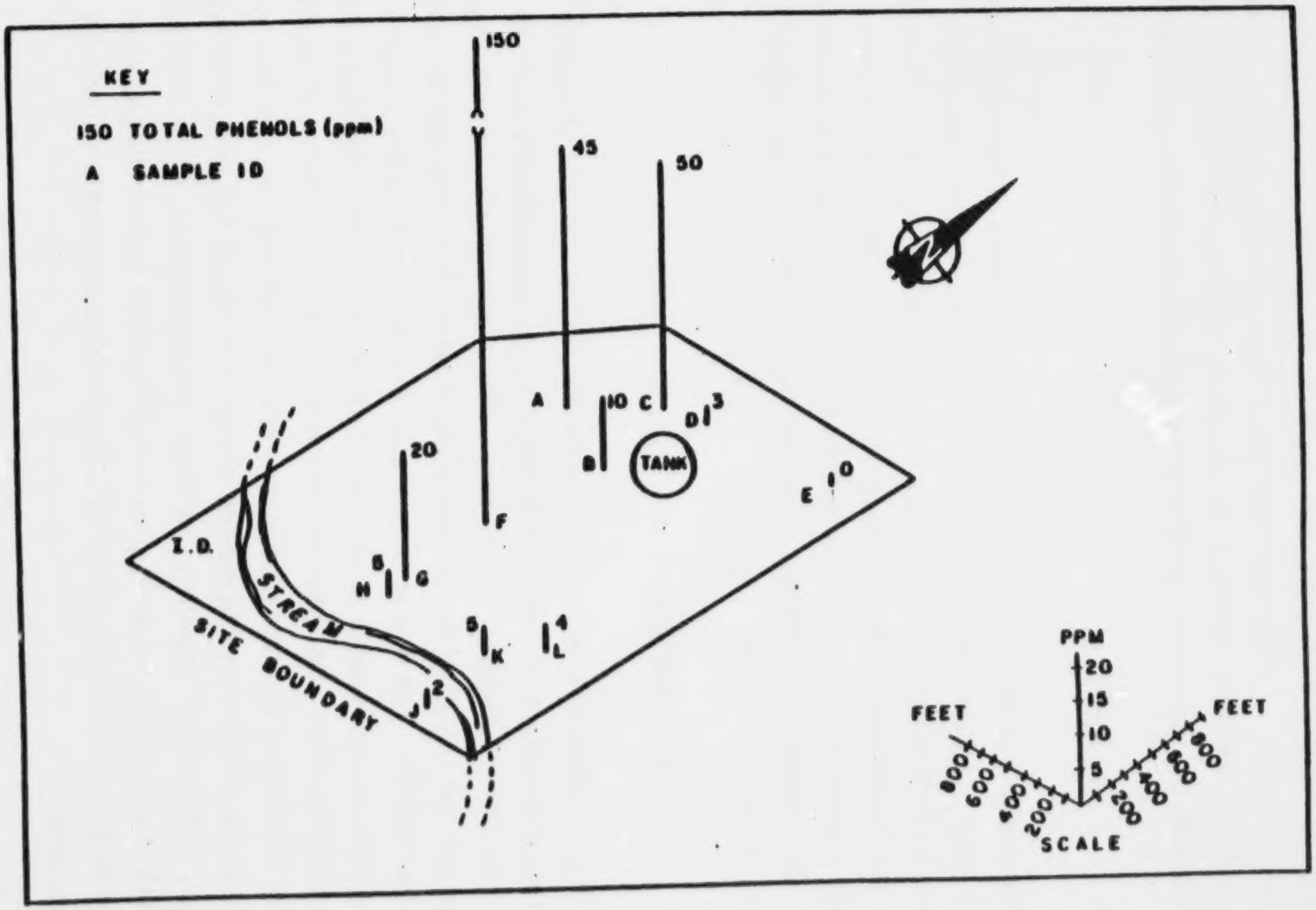

KEY
150 TOTAL PHENOLS (ppm)
A SAMPLE ID
150
45
50
20
10
3
0
8
5
4
2
A
B
C
D
E
F
G
H
J
K
L
TANK
I.D.
STREAM
SITE BOUNDARY
N
PPM
20
15
10
5
FEET
800
600
400
200
FEET
200
400
600
800
SCALE

Figure 5-3. Phenol concentrations in surface soils (ppm = mg/kg)

Contaminant isopleth maps--Lines of equal concentration are called isopleths. Construction of a contaminant isopleth map generally requires a relatively large number of sampling locations spaced regularly across the study area. An isopleth map is prepared by marking the site map with the concentrations detected at each sampling location. Lines are drawn to connect data points of the same concentration, similar to contours of elevation, as shown in Figure 5-4. Figure 5-5 demonstrates the use of an isopleth plot to show the distribution of an air release.

5.2.2.3 Isopach Maps

A technique that is useful for displaying certain types of geological data is the isopach map. Isopachs are contour maps in which each line represents a unit of thickness of a geologic material (e.g., the soil layer) as shown in Figure 5-6. This format would be useful if, for example, oil is known to be contained within a highly permeable sand layer of varying thickness, confined between low permeability clay layers. The isopach map displays thickness only and does not provide information on absolute depth or slope.

5.2.2.4 Vertical Profiles or Cross-Sections

Vertical profiles are especially useful for displaying the distribution of a contaminant release in all media. For soil and ground water, the usual approach is to select several soil cores (or monitoring wells) that lie approximately in a straight line through the center of the contaminant release. This cross-section represents a transect of the site. The owner or operator should then prepare a diagram of the soil (or ground water) profile along the length of the transect, displaying subsurface stratigraphy, location of the source, and the location and depth of boreholes, as shown in Figure 5-7. Concentrations may also be indicated on the plot as discrete measurements or contours and may be drawn as in Figure 5-8. Figure 5-9 presents a plan view of Figure 5-7, showing the offset in cross-section. If the sampling points do not fall in a straight line, an alternate display called a fence diagram can be used. Figure 5-10 shows a fence diagram of subsurface stratigraphy, which also includes analytical data.

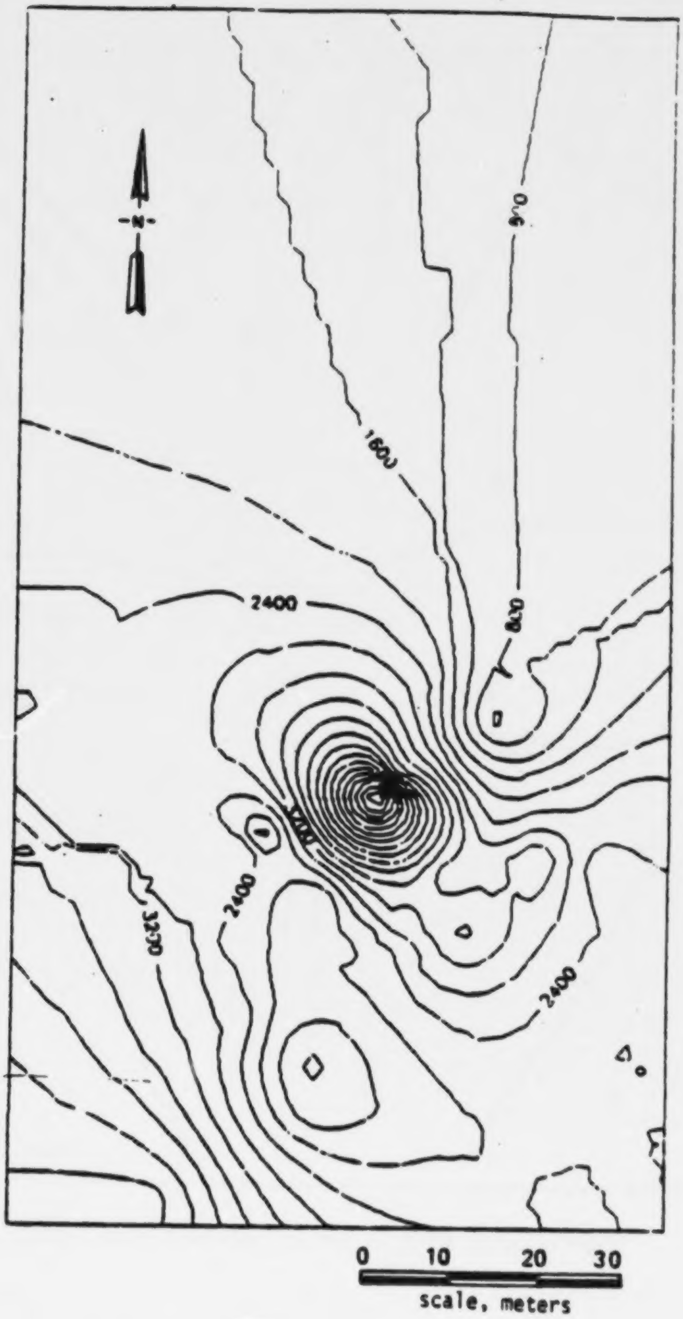
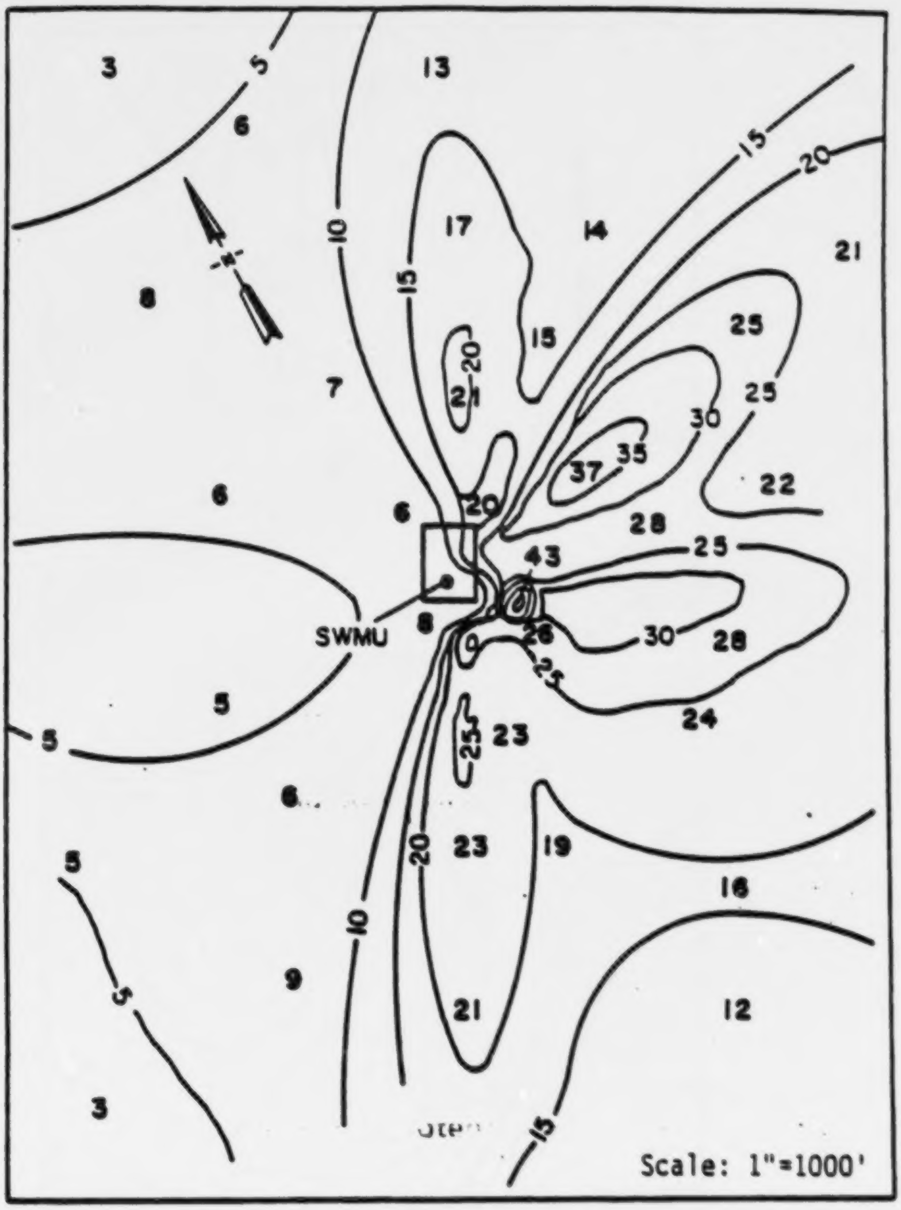

N
800
1600
2400
800
3200
2400
3200
2400
0
10
20
30
scale, meters

Figure 5-4. Isopleth Map of Soil PCB Concentrations (ug/Kg)


3
5
13
6
15
20
17
14
21
10
15
8
20
15
25
21
7
30
25
35
37
22
6
6
20
28
25
43
SWMU
8
26
30
28
25
5
24
5
25
23
6
5
20
23
19
16
10
5
9
21
12
3
15
Scale: 1"=1000'

ISOPLETHS ARE IN MICROGRAMS PER CUBIC METER

Figure 5-5. Isopleth Map of Diphenylamine Concentrations in Ambient Air in the vicinity of a SWMU.

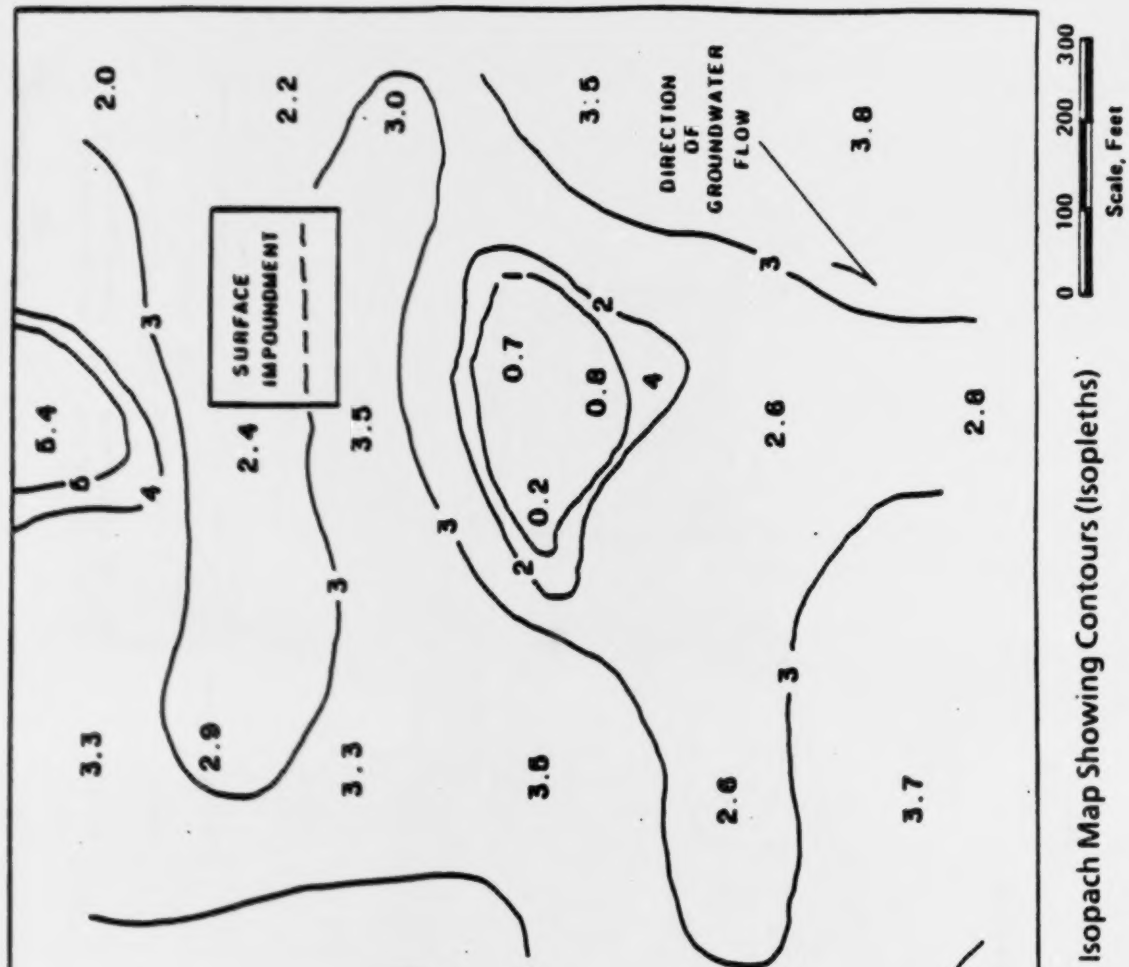

CONTOURS REPRESENT THICKNESS OF SAND LAYER IN FEET
SURFACE IMPOUNDMENT
DIRECTION OF GROUNDWATER FLOW
0
100
200
300
Scale, Feet
2.0
2.2
3.0
3.5
3.8
3
2.4
3.5
5.4
5
4
0.7
0.8
0.2
2
2.6
2.8
3.3
2.9
3.3
3.5
2.6
3.7
4.9
4.8
6.2
6
5.0
5
3.2
3.3
3.6
4.8
4

Figure 5-6. Sand Isopach Map Showing Contours (Isopleths)

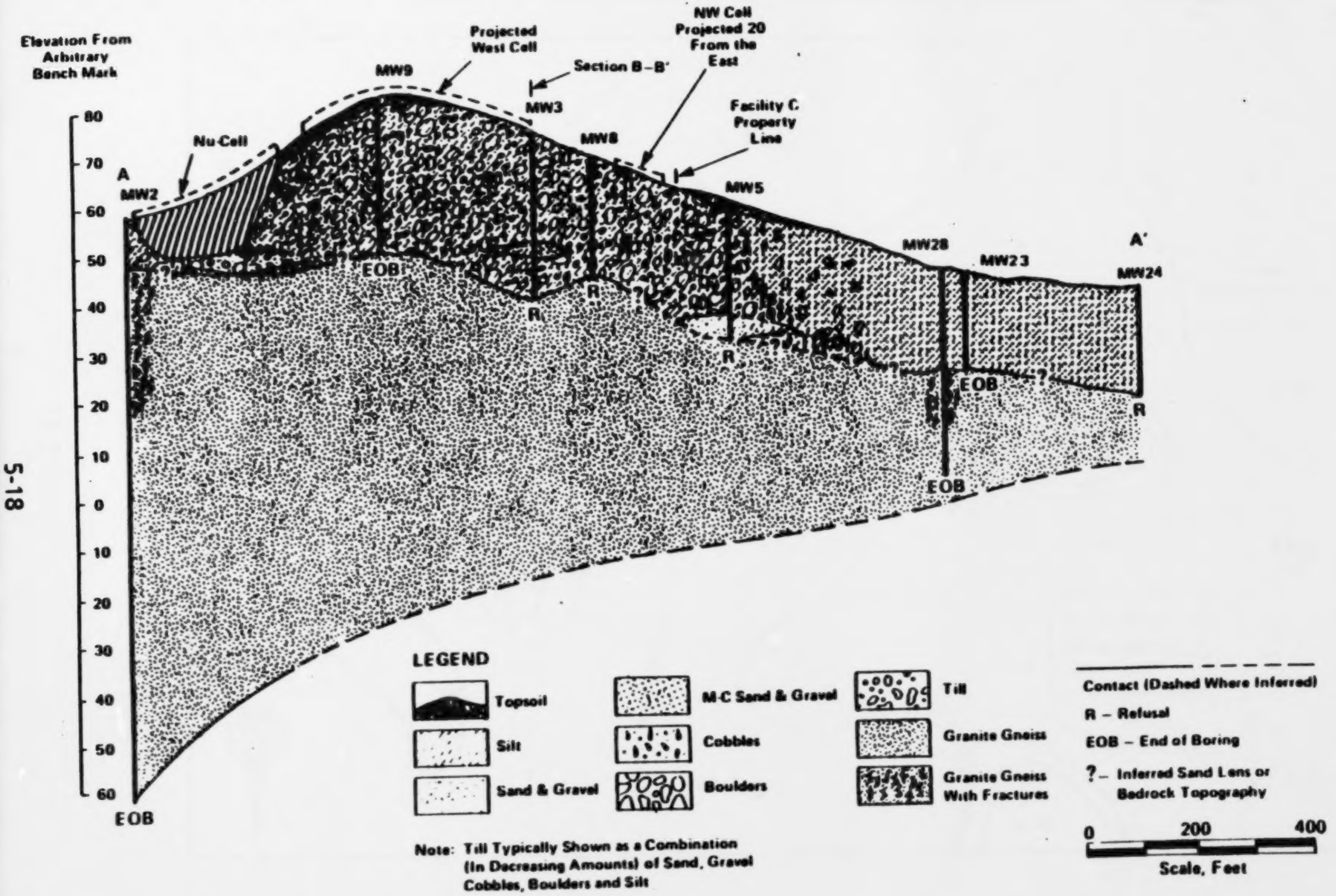

Elevation From Arbitrary Bench Mark
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
EOB
A
MW2
Nu Cell
MW9
Projected West Cell
EOB
Section B-B'
MW3
R
MW8
R
NW Cell Projected 20 From the East
Facility C Property Line
MW5
R
MW28
EOB
MW23
EOB
?
A'
MW24
R
LEGEND
Topsoil
Silt
Sand & Gravel
M-C Sand & Gravel
Cobbles
Boulders
Till
Granite Gneiss
Granite Gneiss With Fractures
Contact (Dashed Where Inferred)
R – Refusal
EOB – End of Boring
?– Inferred Sand Lens or Bedrock Topography
0
200
400
Scale, Feet
Note: Till Typically Shown as a Combination (In Decreasing Amounts) of Sand, Gravel Cobbles, Boulders and Silt

Figure 5-7. Cross Section A-A'-Site Subsurface Profile

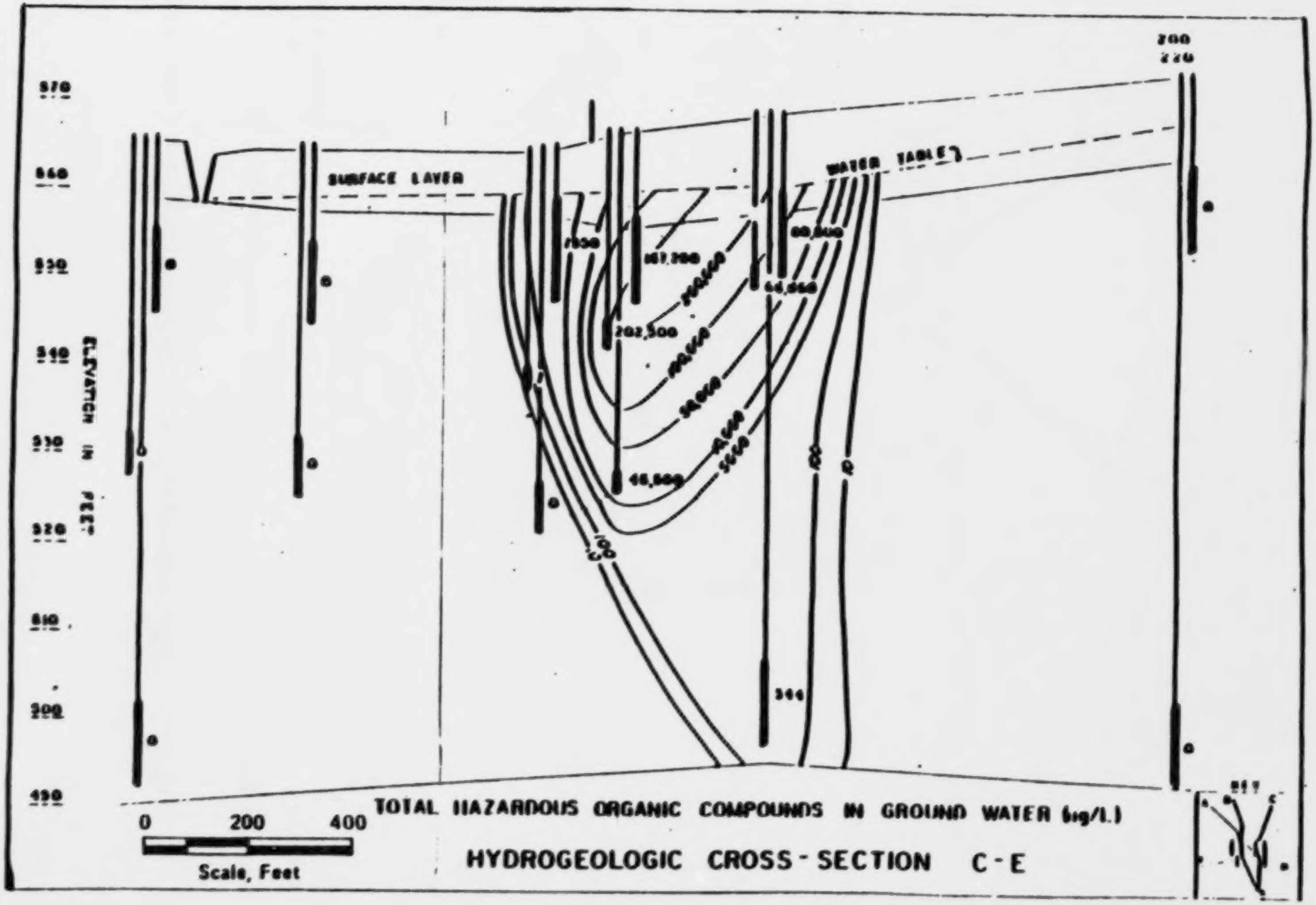

570
560
550
540
530
520
510
500
490
ELEVATION IN FEET
SURFACE LAYER
WATER TABLE(?)
200
220
0
7030
167,200
202,500
60,000
46,800
5500
100
10
344
0
200
400
Scale, Feet
TOTAL HAZARDOUS ORGANIC COMPOUNDS IN GROUND WATER (ug/L)
HYDROGEOLOGIC CROSS-SECTION C-E

Figure 5-8. Transect Showing Concentration Isopleths (ug/l)

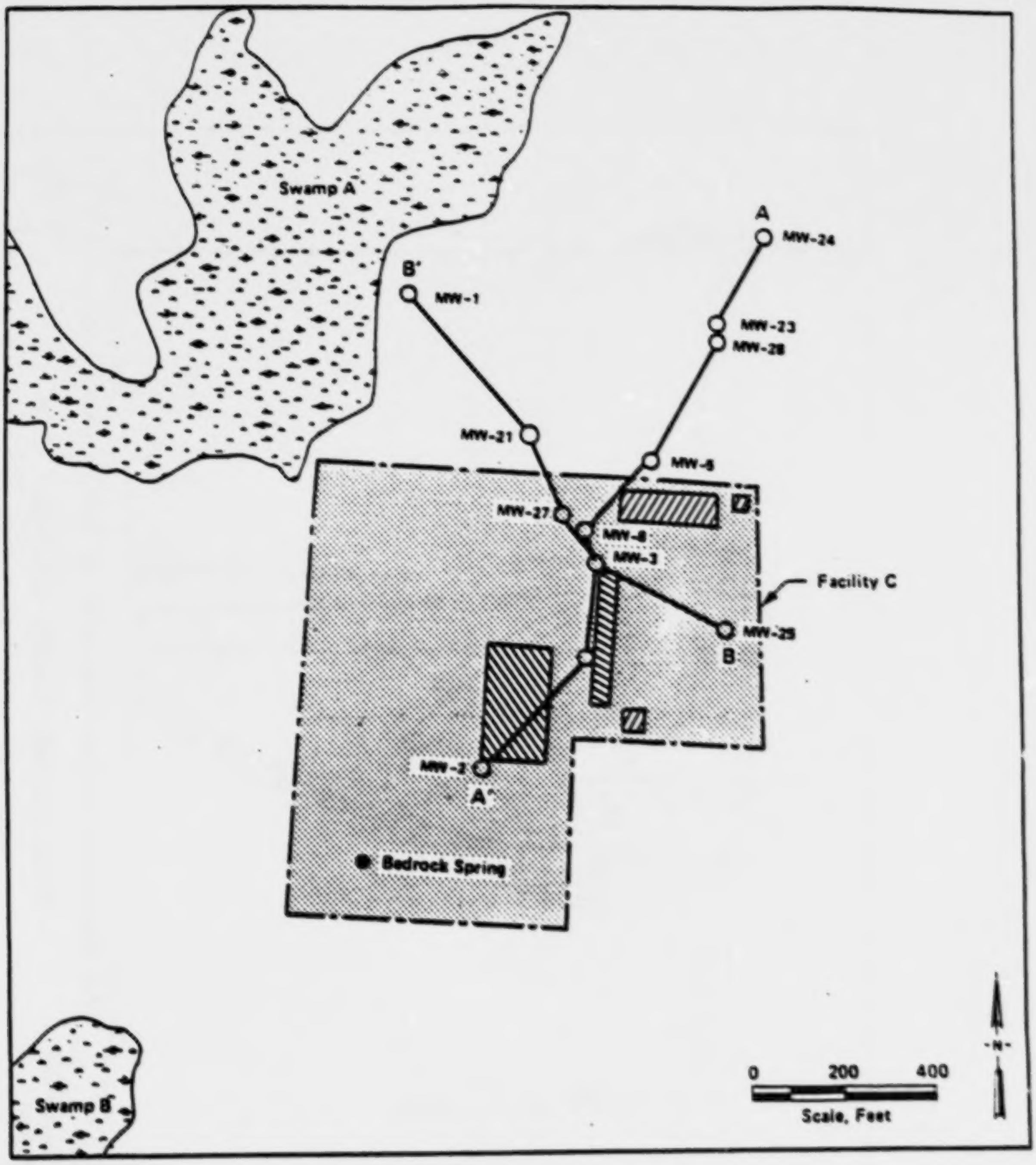
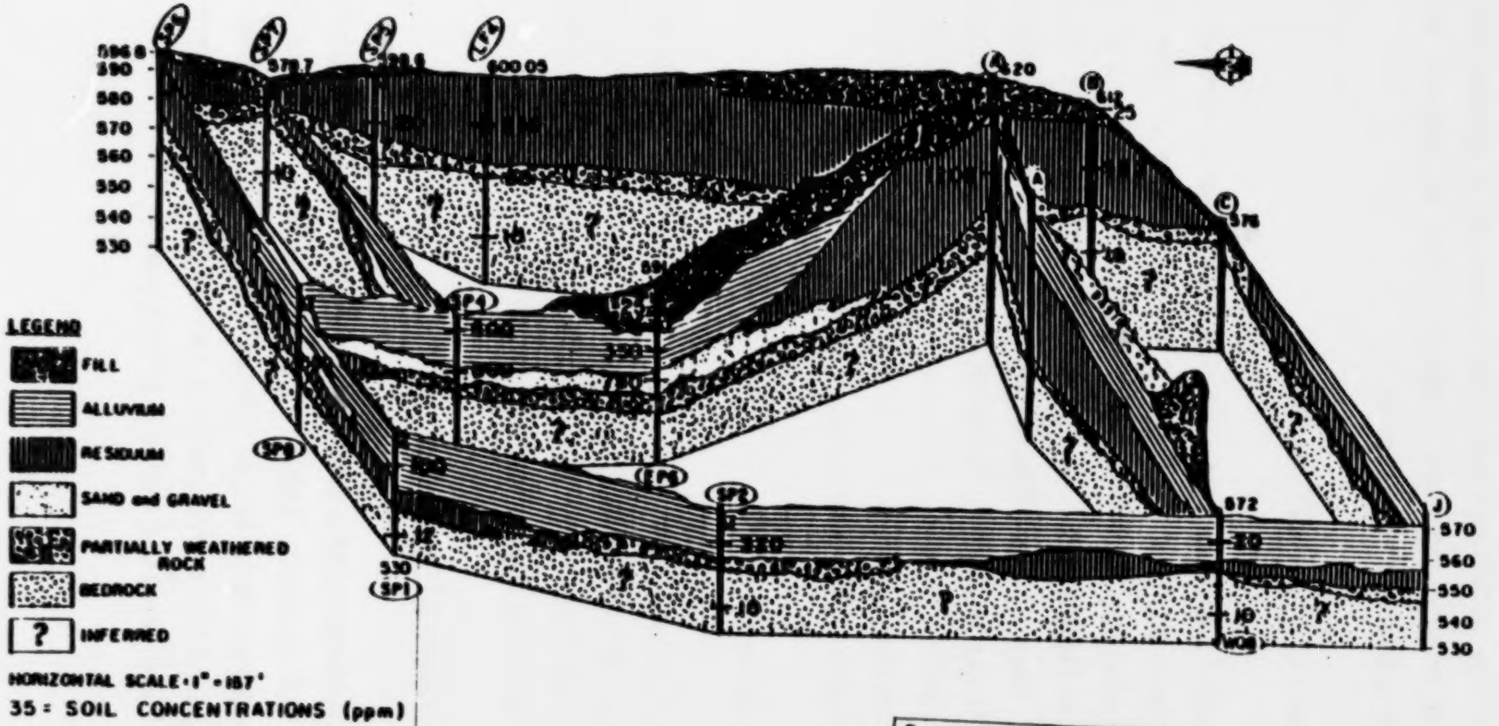

Swamp A
A
MW-24
B'
MW-1
MW-23
MW-28
MW-21
MW-5
MW-27
MW-8
MW-3
Facility C
MW-25
B
MW-2
A'
Bedrock Spring
0
200
400
Scale, Feet
N
Swamp B

Figure 5-9: Plan View of Figure 5-7 Showing Offsets in Cross Section


596.8
590
580
570
560
550
540
530
579.7
600.05
620
612.25
576
572
570
560
550
540
530
SP1
SP2
SP4
SP5
SP6
LEGEND
FILL
ALLUVIUM
RESIDUUM
SAND and GRAVEL
PARTIALLY WEATHERED ROCK
BEDROCK
?
INFERRED
HORIZONTAL SCALE: 1" = 187'
35 = SOIL CONCENTRATIONS (ppm)

Reproduced from best available copy.

Figure 5-10. Fence Diagram of Stratigraphy Showing Lead (Pb) Concentrations (ppm = mg/kg)

5-21

To characterize the 3-dimensional distribution of a subsurface contaminant release, the owner or operator will generally need to prepare several transects crossing the plume in different directions.

5.2.2.5 Three-Dimensional Data Plots

Computer graphics packages are available from several commercial suppliers to produce three-dimensional data plots. A common use of this technique is to represent contaminant concentrations across the study area as a three-dimensional surface, as shown in Figure 5-11. The information provided by this approach does not differ greatly from that of Figure 5-4. The primary difference is that the smoothing of the concentration differences between adjacent sampling locations in Figure 5-11 makes patterns in the data easier to visualize. Precise concentrations, however, cannot be displayed in this format because the apparent heights of the contours change as the figure is rotated.

5.3 Data Reduction

Data should be reported according to accepted practices of quality assurance and data validation. All data should be reported. Considerations, however, include treatment of replicate measurements, identification of outlier values, and reporting of results determined to be below detection limits.

5.3.1 Treatment of Replicates

Replicate measurements of a single sample should be averaged prior to further data reduction. For example, Table 5-5 shows how to calculate an overall mean when replicate analyses for a single sample have been performed. The three "B" values are averaged before the mean is calculated. This removes bias from the overall mean. "n" indicates the number of analyses.

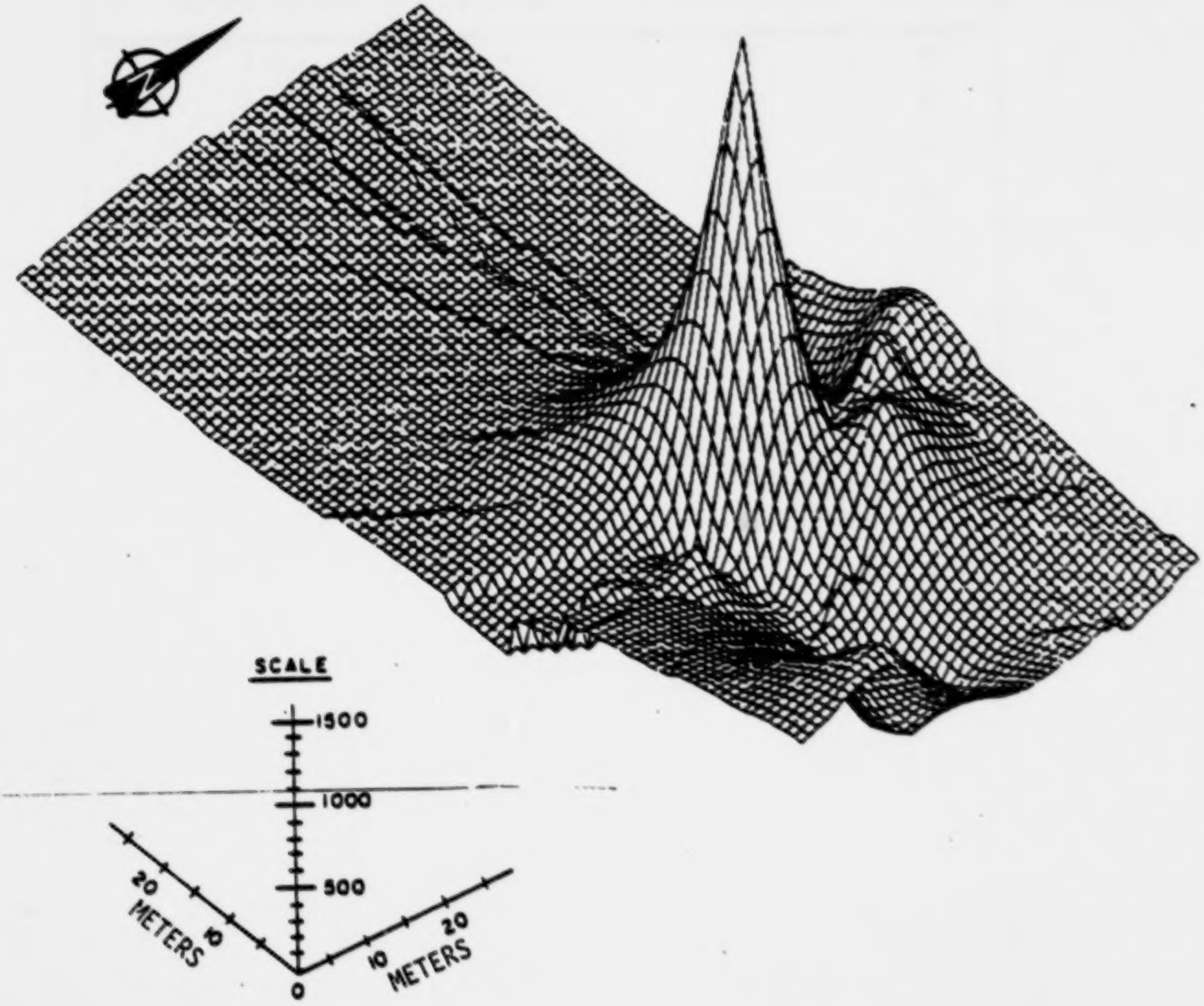


Figure 5-11. Three-Dimensional Data Plot of Soil PCB Concentrations (ug/Kg)

Table 5-5

Calculation of Mean Values for Replicates

Raw Data		Data Summary		
Sample	Concentration	Sample	Concentration	n
A	4.3	A	4.3	1
B	1.8	B	1.8	3
B	2.0	C	7.6	1
B	1.6	D	6.3	1
C	7.6			
D	6.3	mean [(A + B + C + D)/4]	5.0	6

5.3.2 Reporting of Outliers

Any program of environmental measurement can produce numbers that lie outside the "expected" range of values. Since field variability of environmental measurements can be great, deciding whether an extreme (outlier) value is representative of actual contaminant levels may be difficult. Outlier values may be the result of:

- A catastrophic unnatural (but real) occurrence such as a spill;
- Inconsistent sampling or analytical chemistry methodology;
- Errors in the transcription of data values or decimal points; and
- True but extreme concentration measurements.

The owner or operator should attempt to correct outlying values if the cause of the problem can be documented. The data should be corrected, for example if outliers are caused by incorrect transcription and the correct values can be obtained and documented from valid records. Also, if a catastrophic event or a problem in methodology occurred that can be documented, data values should be reported with clear reference. Documentation and validation of the cause of outliers must accompany any attempt to correct or delete data values, because true but extreme values must not be altered. Statistical methods for identifying outliers require that the analytical laboratory have an ongoing program of quality assurance, and that sufficient replicate samples be analyzed to account for field variability.

Outlier values should not be omitted from the raw data reported to the regulatory agency; however, these values should be identified within the summary tables.

5.3.3 Reporting of Values Below Detection Limits

Analytical values determined to be at or below the detection limit should be reported numerically (e.g., $\leq$0.1 mg/l). The data presentation procedures should cite analytical methods used including appropriate detection limits.

5.4 Reporting

As indicated in Section 3.7, the owner or operator should respond to emergency situations and identify priority situations that may require interim corrective measures to the regulatory agency. Such reporting should be done immediatley. In addition, results of various activities conducted during the RFI should be reported to the regulatory agency, as required in the compliance order or by the permit conditions.

Various reports may be required. These may include interim, draft, and final reports. In addition, periodic progress reports (e.g., bimonthly) may also be required. Progress reports should include the following information:

- A description and estimate of the percentage of the RFI completed;
- Summaries of all findings;
- Summaries and rationale for all changes made in the RFI Work Plan during the reporting period;
- Summaries of all contacts with representatives of the local community, public interest groups, or government representatives during the reporting period;
- Summaries of all problems or potential problems encountered during the reporting period;
- Actions being taken to rectify problems;
- Changes in personnel during the reporting period;
- Projected work for the next reporting period; and
- Copies of daily reports, inspection reports, laboratory/monitoring data, etc.

Reports, including interim, progress, draft, and final reports may also be required for specific activities that may be performed during an RFI. Examples of specific reports that may be reuqired include:

- RFI Work plan;
- Description of Current Situation;
- Geophysical Techniques;
- Waste and Unit Characterization;
- Environmental Setting Characterization;
- Selection of Monitoring Constituents/Indicator Parameters;
- Results of "Phases" of the Investigation;
- QA/QC results;
- Interim Corrective Measures;
- Identification of Potential Receptors; and
- Exposure Assessment.

In addition, a draft and final RFI report which incorporates the results of all previous reports will generally be required. This report should be comprehensive in nature and should be sufficiently detailed to allow decisions to be made by the regulatory agency regarding the need for interim corrective measures and/or a Corrective Measures Study. It should be noted that these decisions may have already been made by the regulatory agency on the basis of results of progress and/or other reports as described above.

SECTION 6

HEALTH AND SAFETY

6.1 Overview

Protecting the health and safety of the investigative team, as well as the general public, is a major concern during hazardous waste facility investigations. Hazards to which workers may be exposed include known and unknown chemicals, heat stress, physical stress, biological agents, equipment-related injuries, fire, and explosion. Many of these hazards are encountered in any type of field study, but exposure to chemical hazards, including toxicity, are major concerns for the investigative team at hazardous waste facilities.

In addition to the protection of team members, the public's health and safety should also be considered. RCRA facility investigations may attract the news media, public officials, and the general public. Not only is the safety of these observers a concern, but their actions should not hinder the operations and safety of the investigative team. Other public health concerns include risks to the surrounding community from unanticipated chemical releases, and events such as fire and explosion.

The facility owner or operator should develop and update as necessary health and safety procedures to address the needs of the RFI. The procedures should establish requirements for protecting the health and safety of the investigative team, facility workers, and the general public throughout the investigation. They should be prepared and reviewed by qualified personnel (e.g., a certified industrial hygienist), and should be discussed thoroughly with the investigative team prior to field activities. Other appropriate parties (e.g., local emergency services) should also be involved, as appropriate.

The development and implementation of health and safety procedures is the responsibility of the owner or operator. Although these procedures may be presented as part of the RFI Work Plan and reviewed by the regulatory agency, ultimate responsibility and liability rests with the owner or operator. Section 6.2 presents general health and safety regulations and guidance which should be reviewed prior to developing health and safety procedures, and Section 6.3 outlines basic elements of health and safety procedures which should be addressed.

Case Study Number 30 in Volume IV (Case Study Examples) provides an example of a Health and Safety Plan.

6.2 Applicable Health and Safety Regulations and Guidance

On December 19, 1986, the Occupational Safety and Health Administration (OSHA) issued, in the Federal Register (29 CFR 1910.120), an interim final rule on hazardous waste site investigations, which specifically requires certain minimum standards concerning health and safety for anyone performing activities at CERCLA sites, RCRA sites, or emergency response operations. Highlights of this interim final rule are summarized below:

- Establishment of site work zones, the use of the "buddy system," and good site communications is required.

- Site employees must undergo a minimum of 40 hours of initial training, three days of on-the-job training, and a minimum of eight hours annual refresher training. On-site training is also addressed in the standard.

- Site managers and supervisors directly responsible for site operations are to receive the same training plus an additional eight hours of training in managing such operations.

- Medical surveillance (specifically physical examination) requirements are addressed (baseline, periodic, certain pre-job examinations). The employer must provide the examining physician with information regarding exposure, respirator use, and site duties. Chapter 5 of Reference 6 of the standard must be supplied to the physician, and the physician (not the employer) is to determine what the examination is to consist of. The employer is also to pay the cost of the examination and pay the person's wages during the exam.

- Site specific health and safety plans are required, and their contents must include at least that which is specified in 1910.120(i)(2).

- On initial site entries (i.e., site reconnaissance), a 5-minute escape SCBA (Self Contained Breathing Apparatus) must be carried by site personnel, or kept available at their immediate work station.

- Unless a preliminary (off-site records search) evaluation can produce sufficient information to rule out the need for Level B PPE (i.e., personal protective equipment which generally provides for respirators and dermal protection), it shall be provided as a minimum level of protection for initial site entries.

- The standard also contains requirements on decontamination, site water supplies, toilet facilities, illumination, etc.

Following is a list of other regulations that should be considered when developing the health and safety procedures:

Citation	Title
29 CFR 1903	Inspections, Citations, and Proposed Penalties
29 CFR 1904	Recording and Reporting of Occupational Injuries and Illnesses
29 CFR 1926	Safety and Health Regulations for Construction
29 CFR 1960	Federal Employee Safety and Health Programs
29 CFR 1975	Coverage of Employers Under the Occupational Safety and Health Act
29 CFR 1977	Regulations on Discrimination Against Employees Exercising Rights Under the Occupational Safety and Health Act

Other Federal and state regulations may also address the health and safety of the investigative team and the public. Department of Transportation (DOT) regulations (49 CFR 171-178), for example, specify containers, labeling, and transportation restrictions for hazardous materials. These regulations cover the transport of compressed air cylinders, certain instruments, solvents, and samples. The Resource Conservation and Recovery Act (RCRA) regulations (40 CFR 260-265) may apply to the storage, treatment, and disposal of investigation-derived materials, including disposable clothing, used respirator cartridges and canisters, and spent decontamination solutions.

Individual states may have occupational safety and health regulations more stringent than OSHA's. These should be consulted in order to determine their applicability and to ensure compliance. In addition, several guidance manuals exist that may be helpful in establishing health and safety procedures. These are listed below:

- Ford, P. J. and Turina, P. T. 1985. Characterization of Hazardous Waste Sites--A Methods Manual: Volume I--Site Investigations. EPA- 600/4-84/075. NTIS PB 85-215960. Washington, D.C. 20460.
- U.S. EPA. 1984. Standard Operating Safety Guides. Office of Emergency and Remedial Response. Washington, D.C. 20460.
- NIOSH. 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities. NIOSH 85-115. GPO No. 017-003-00419-6.
- U.S. EPA. 1985. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response. NTIS PB 85-238616. Washington, D.C. 20460.
- U.S. EPA. 1986. Occupational Health and Safety Manual. EPA 1440.
- U.S. EPA. Order 1440.2 - Respiratory Protection.
- U.S. EPA. Order 1440.3 - Health and Safety Requirements for Employees Engaged in Field Activities.

Professional recommendations and standards have also been offered by organizations such as the American Conference of Governmental Industrial

Hygienists, the American Society of Testing and Materials, the American National Standards Institute, and the National Fire Protection Association.

6.3 Elements of Health and Safety Procedures

RFI health and safety procedures should address the following:

- Describe any known hazards and their associated risks;
- List key personnel and alternates responsible for site safety, response operations, and protection of the public;
- Describe protective equipment to be worn by investigative personnel;
- Delineate work areas;
- Establish procedures to control site access;
- Describe decontamination procedures for personnel and equipment;
- Establish site emergency procedures, including emergency medical care for injuries and toxicological problems;
- Describe requirements for an environmental surveillance program;
- Specify any routine and special training required for personnel responding to environmental or health and safety emergencies; and
- Establish medical monitoring program for personnel.

SECTION 7

WASTE AND UNIT CHARACTERIZATION

7.1 Objectives and Purposes of Waste and Unit Characterization

Because the waste managed or contained in a unit provides the source for a contaminant release, detailed knowledge of the source characteristics is valuable in identifying monitoring constituents and indicator parameters, possible release pathways, a conceptual model of the release, monitoring procedures, and also in linking releases to particular units. Waste and unit characteristics will also provide information for determining release rates and other release characteristics (e.g., continuous as opposed to intermittent). Waste and unit information is also important for determing the nature and scope of any corrective measures which may be applied.

Without adequate waste information, it is difficult to assure that all constituents of concern will be monitored during the release investigation, unless all possible constituents are monitored. The extent of adequate waste characterization, however, will vary depending upon the nature of the facility and types of units being studied. For example, waste characterization for a unit dedicated to a single steady-state process will be much less extensive than for a unit at an offsite facility that manages a variety of wastes, which vary over time.

As indicated above, waste characterization may also be helpful in identifying constituents to discriminate releases from different units. In some situations (e.g., where there is more than one unit in a waste management area), it may be important to identify which unit is responsible for the release of concern. Accurate identification of the unit from which the release is occurring may hinge on the ability to link the released contaminants to the waste managed in a particular unit (or, in some cases, to "decouple" the contamination from a particular unit).

Sufficient characterization of the waste for the purpose of the RFI may not be possible due to the diversity of wastes managed in the unit over time or the relative inaccessibility of the waste in the unit. Waste characterization may be of limited utility where:

- The waste managed in the unit varies over time such that adequate determination of the waste constituents cannot be made. An example of this is an offsite commercial facility receiving different wastes from different generators.

- The unit of concern is no longer active and the waste cannot be sampled through a reasonable effort. This situation may occur at closed landfills where sampling of buried drums may not be practical due to their inaccessibility.

In certain situations waste characterization may also not be advisable. For example, the waste in question may be extremely toxic (e.g., nerve gas), or highly reactive or explosive (e.g., disposed munitions). In such cases, release characterization may be based on constituents (or parameters) identified in the affected media (e.g., leachate) at the point where the media becomes (or is suspected of becoming) contaminated. If it becomes necessary to conduct waste characterizations in these situations, or to remove the waste in question, a high level of health and safety protection (See Section 6) should be instituted.

Waste characterization should also be designed to provide sufficient information to support remedial and removal actions. For example, if buried drums are identified during the investigation, the nature of the waste within these drums (e.g., ignitability, corosivity, reactivity, constituent concentrations), if accessible, should be ascertained to determine if they should be removed from the site and how they should be subsequently managed as well as to support the investigation of media-specific releases under the RFI.

Design and operational characteristics of the unit are factors that will affect the rate of release and location within the unit from which the contamination is or has been released. Such factors as unit size, type, operational schedule, and treatment, storage, or disposal practices should be helpful.

Although 40 CFR Section 264.13 of the RCRA regulations (General Waste Analysis) contains waste analysis requirements, the information required may not always be sufficient for purposes of the RFI. Waste characterization to determine specific hazardous constituents, for instance, is not always required. In addition, little or no data on inactive units may be available. The RFI Work Plan should be consistent, as appropriate, with the items identified in the requirements of 40 CFR Section 264.13. Further guidance is given below.

7.2 Waste Characterization

In cases where a waste characterization is to be performed, the following approach is recommended:

- Identify data needs through review of existing information;
- Sample the waste; and
- Characterize the physical and chemical properties of the waste and waste consitutents.

If the unit has a leachate collection system, the leachate should also be sampled and analyzed, as it may also provide useful information, particularly with respect to the leachable portions of wastes contained in the unit.

7.2.1 Identification of Relevant Information

In general, a waste characterization should produce the following types of information:

- Identification of specific hazardous constituents and parameters which can be used in release verification or characterization (See Section 3.6);
- Physical and/or chemical characteristics of the waste useful for identifying possible migration pathways through the environmental media of concern; and

- Physical and/or chemical characteristics of the waste which may be necessary to evaluate treatment and/or management options.

Identifying specific constituents of the waste through a sampling and analysis program may require an extensive level of effort. The owner or operator is advised to use various informational sources on the specific waste in question in order to focus the analytical effort required. Such sources are described below.

7.2.1.1 EPA Waste Listing Background Document Information

The RCRA Hazardous Waste Listing Background Documents developed for the identification and listing of hazardous wastes under 40 CFR Part 261 contain information on waste-specific constituents and their physical and chemical characteristics. These documents contain information on the generation, composition, and management of listed waste streams from generic and industry-specific sources. In addition to identifying hazardous constituents that are present in the wastes, the documents may also provide data on potential decomposition products. In some background documents, migratory potential is discussed and exposure pathways are identified.

Appendix B of the Listing Documents provides detailed information on the fate and transport of hazardous constituents. Major physical and chemical properties of selected constituents are listed, including molecular weights, vapor pressures and solubilities, octanol-water partition coefficients, hydrolysis rates, biodegradation rates, volatization rates, and air chemistry (e.g., reaction) rates. Another section of this appendix estimates the migratory potential and environmental persistence of selected constituents based on a conceptual model of disposal in an unconfined landfill or lagoon.

The appropriate uses and limitations of the Listing Documents are outlined in Table 7-1. In addition, Case Study No. 16 in Volume IV (Case Study Examples) illustrates the use of the Listing Documents.

A list of the available listing background documents may be obtained by reviewing 40 CFR Part 261.31 and 261.32. These background documents are available in EPA's RCRA docket at the following location:

Table 7-1

Uses and Limitations of EPA Listing Background Documents

Uses	Limitations
• Identifies the hazardous consituents for which a waste was listed.	• Applicable only for listed hazardous wastes.
• In some cases, provides information on additional hazadous constituents that may be present in a listed waste.	• Industry coverage may be limited in scope. For example, the Wood Preserving Industry Listing Document only covers organic preservatives. Inorganics such as inorganic arsenic salts, account for approximately 15 percent of the wood preserving industry.
• In some cases, identifies decomposition products of hazardous constituents.	• Data may not be comprehensive. For example, not all potentially hazardous constituents may be identified. Generally, only the most toxic constituents common to the industry as a whole are identified.
• Provides overview of industry; gives perspective on range of waste generated (both quantity and general characteristics).	• Data may not be specific. Constituents and waste characteristics data often represent an industry average which encompasses many different types of production processes and waste treatment operations.
• May provide waste-specific characteristic data such as density, pH, and leachability.	• Some Listing Documents were developed from limited data/reports available to EPA at the time of promulgation, resulting in varying levels of detail for different documents.
• May provide useful information on the migratory potential, mobility, and environmental persistence of certain hazardous constituents.	• Listing Documents for certain industries (e.g., the Pesticides Industry) may be subject to CBI (confidential business information) censorship. In such cases, constituent information may be expurgated from the document.
• May list physical and chemical properties of selected constituents.	

EPA RCRA Docket
U.S. Environmental Protection Agency (WH-562)
Room S-212
401 M St., S.W.
Washington, D.C. 20460

An additional reference that may be helpful in identifying constituents from listed hazardous wastes is:

U.S. EPA. 1984. Characterization of Constituents from Selected Waste Streams Listed in 40 CFR Section 261. Prepared by Environ Corporation for the Office of Solid Waste. Washington, D.C. 20460.

7.2.1.2 Facility Information

Identification of the constituents of a waste stream may be made through examination of records already existing in the facility. Engineering data on process raw materials or analytical data on the process effluents will also provide a good starting point for waste characterization. In some cases, generally where waste characteristics are well defined, data on process raw materials or effluents will provide sufficient information for performing the RFI. More specifically, these sources may be:

- Hazardous waste characterization data used for a RCRA Permit Application;
- Waste Analysis Plan (as required by 40 CFR Part 264.13);
- State or local permit applications;
- Initial batch treatment results from an offsite hazardous waste disposal facility;
- Hazardous waste compatibility results for bulk shipments;

- Purchase orders and packing lists;
- Analyses conducted to provide data for shipping manifests;
- Facility records of past waste analyses;
- Process operational data;
- Product quality control analyses;
- Data from past releases of hazardous waste into the environment;
- Compatability results for containment liner studies;
- Past Federal, State or local compliance and inspection results;
- Occupational Safety and Health Administration (OSHA) industrial hygiene monitoring results;
- Facility health and safety monitoring data;
- Engineering design data from construction of plant processes;
- Performance specifications for process equipment;
- Related emissions data such as NPDES discharge results; and
- Information from past or present employees.

7.2.1.3 Information on Physical/Chemical Characteristics

Information on physical or chemical characteristics of the waste or waste constituents that may be useful in predicting movement of the contamination through the media of concern or in evaluating waste treatment or management options may be found in the following references:

Callahan *et al*. 1979. *Water-Related Environmental Fate of 129 Priority Pollutants, Volumes I and II.* Office of Water Planning and Standards. NTIS PB 297606. Washington, D.C. 20460.

Dawson, *et al*. 1980. *Physical/Chemical Properties of Hazardous Waste Constituents.* Prepared by Southeast Environmental Research Laboratory for U.S. EPA. EPA RCRA Docket. Washington, D.C. 20460.

U.S. EPA. 1985. Health Effects Assessment for [Specific Chemical]. [Note: 58 individual documents available for specific chemicals or chemical groups]. Environmental Criteria and Assessment Office. Cincinnati, Ohio 45268. [See Section 8.4 for a list of these documents]

Jaber, *et al*. 1984. *Data Acquisition for Environmental Transport and Fate Screening.* Office of Health and Environmental Assessment, U.S. EPA. EPA 600/6-84-009. NTIS PB 84-140102. Washington, D.C. 20460.

Lyman, *et at*. 1982. *Handbook of Chemical Property Estimation Methods*. McGraw-Hill, New York.

Mabey, *et al*. 1982. *Aquatic Fate Process Data for Organic Priority Pollutants.* Prepared by SRI International, EPA Contract Nos. 68-01-3867 and 68-03-2981. Prepared for Office of Water Regulations and Standards. Washington, D.C. 20460.

U.S. EPA. 1980. *Treatability Manual, Volume I*. EPA 600/2-82-001a. Office of Research and Development. NTIS PB 80-223050. Washington, D.C. 20460.

U.S. EPA. 1984. *Characterization of Constituents from Selected Waste Streams Listed in 40 CFR Section 261.* Office of Solid Waste. Washington, D.C. 20460.

U.S. EPA. 1984. *Exposure Profiles for RCRA Risk-Cost Analysis Model.* Office of Solid Waste. Washington, D.C. 20460.

U.S. EPA. 1986. *Ambient Water Quality Criteria*. Office of Water Regulations and Standards. Washington, D.C. 20460.

Perry and Chilton. 1973. Chemical Engineers' Handbook. McGraw-Hill. 5th Ed. New York.

Verschueren. 1983. Handbook of Environmental Data for Organic Chemicals. Van Nostrand Reinhold Co. New York. 2nd ed.

Weast *et al*. 1979. CRC Handbook of Chemistry and Physics.

Windholtz, *et al*. 1983. The Merck Index. Merck & Co. Rahway, NJ.

U.S. EPA. 1986. Test Methods for Evaluating Solid Wastes. 3rd Edition. Office of Solid Waste. EPA/SW-846. GPO No. 955-001-00000-1. Washington, D.C. 20460.

U.S. EPA. 1984. Characterization of Hazardous Waste Sites--A Methods Manual. Volume III. Available Analytical methods. EPA 600/4-84-038. NTIS PB 84-191048. Washington, D.C. 20460.

Some commercially available computer information systems that contain chemical properties data and/or estimation methods may also be used. An example would be the CIS or Chemical Information System (7215 York Road, Baltimore, MD 21212). Another example is the GEMS (Graphical Exposure Modeling System) data base discussed Section 3.5. The owner or operator should consult with the regulatory agency prior to use of such systems.

7.2.1.4 Verification of Existing Information

If existing information is current and sufficient to completely identify the type, amount, and location of waste, then available information may be considered adequate. If existing information is used, the constituents present should be verified by recent waste analysis or by dated analysis that is substantiated by recent facility records showing that no changes in process, manufacturing, or other practices that could alter waste composition have occurred. If existing information does not provide adequate waste characterization, or if the waste characteristics have changed, a sampling effort may be required.

7.2.2 Waste Sampling

All sampling should be conducted in a manner that maintains sample integrity and encompasses adequate quality assurance and control. The characterization of waste in any unit must be representative. Wastes are often generated in bulk quantities from a large variety of processes. Adequate determination of the waste profile requires that cyclical or random variations in the waste composition be considered. The characterization should account for variation in waste content by collecting samples that are representative of all potential waste variations. If a wide variation in waste composition is expected, it is preferable to document the range of this variation through the analysis of numerous samples. If little variation is anticipated, a lesser amount of sampling may be appropriate. If composite sampling is proposed, it must not mask unexpected or unanticipated compositional variations, and should always be complemented with an appropriate number of grab (non-composited) samples. Generally, compositing should not be used when evaluating variation in waste composition. The collection of representative samples will involve different procedures for different waste and unit types. This is discussed further in Section 7.4.

7.2.3 Physical/Chemical Waste Characterization

Compound specific waste characterization should consider the constituents listed in 40 CFR Part 261, Appendix VIII, as the universe of overall constituents. Except for especially complex waste, many of the compounds on this list may be eliminated using the guidance presented previously in this section and in Section 3.6. As indicated in Section 3.6:

- The owner or operator should provide a sound justification or analytical results of waste analyses as substantiation for the elimination of constituents from further consideration;

- The analysis of waste samples to determine their characteristics should be performed using standard methods, suchs as those described in the 3rd edition of EPA/SW-846 (Test Methods for Evaluating Solid Waste), or equivalent methods; and

- A detailed QA/QC Plan should clearly define the sample preparation techniques, analytical methodology, required analytical sensitivities and detection limits, collection of blanks and duplicates.

In addition, for units that contain a mixture of solid, sludge and/or liquid waste material, each phase should be analyzed and volume proportions measured. Case Studies No. 13, 18, 19 and 21 in Volume IV (Case Study Examples) provides illustrations of waste sampling uses, considerations and techniques.

7.3 Unit Characterization

Information on unit characteristics may affect release properties and pathways. The owner or operator should obtain relevant information on the unit for use in developing the investigation strategy. Such information may include:

- Unit dimensions (including depth below grade);
- Unit type;
- Unit purpose (e.g., biodegradation);
- Structural description, including materials and methods of construction, and any available drawings
- Amounts of waste managed;
- Previous uses of area occupied by unit;
- Unit location;
- Description of liner or cap materials;
- Holding/retention time;
- Key operating parameters, such as waste management schedule;

- Waste treatment/application or loading rate;
- Biological activity present;
- Vent numbers and sizes; and
- Drainage areas.

7.4 Applicable Waste Sampling Methods

7.4.1 Sampling Approach

References for waste sampling methods discussed in this section are listed in Section 3.6.3. A summary of available waste sampling methods for various waste matrices are provided in Table 7-2.

The collection of waste samples requires methodology suited to the type of waste and unit being sampled. In addition, waste sampling requires specialized equipment and protocols that may be designed especially for waste analysis or adapted from other sampling methods. Several important points to consider when developing a sampling approach are:

- Compatability of sampling methods and materials with the constituents being sampled.
- Ensuring the safety of personnel. Careful attention should be given to the level of protection and safe practices required for sampling activities. If the sampler is wearing protective gear that limits vision and mobility, or is fatiguing to wear, the collection procedures should be as simple as possible.
- Waste samples are generally not preserved and are considered hazardous for shipping purposes.

TABLE 7-2. SAMPLING METHODS SUMMARY FOR WASTE CHARACTERIZATION

Waste Type/Unit Type	1 Scoops and Shovel	2 Triers	3 Thiefs	4 Augers	5 Core Samplers	6 Glass Tubes	7 Petite Ponar Grab	8 Dippers	9 Coliwasa	10 Pump and Tubing	11 Kemmerer Bottle	12 Bacon Bomb
Solid Wastes												
Waste Piles	X	X	X	X								
Land Treatment Units	X				X*							
Landfills				X	X							
Drum Handling	X		X									
Sacks and Bags	X	X	X									
Trucks	X	X	X		X							
Conveyor Belts	X											
Unloading/Loading/ Transfer Areas	X				X							
Sludge Wastes												
Waste Piles	X	X			X		X					
Drum Handling	X				X	X			X			
Tanks	X							X	X			
Surface Impoundments	X						X	X	X			
Trucks	X	X			X		X	X				
Conveyor Belts	X	X										
Unloading/Loading/ Transfer Areas					X	X		X				
Liquid Wastes												
Drum Handling						X		X	X	X		
Tanks									X	X	X	X
Surface Impoundments								X	X	X	X	X
Trucks								X		X	X	X
Unloading/Loading/ Transfer Areas								X		X		X

* Core Sampler modified to serve as air-tight container for retention of volatile fraction.

7.4.2 Sampling Solids

Sampling of solid materials should utilize readily available techniques. In general, the primary concern for the sampling of solid materials is effectively representing a large amount of possibly heterogeneous material in small samples. In order to address this concern, discrete samples should be collected from sufficient locations to characterize the waste with respect to location and time. Sampling methods vary depending on whether samples are to be collected at the surface, or below the surface. For a unit currently in operation, variation in the waste stream composition over time should be considered in determining when samples should be taken.

For large amounts of solid materials, sample locations may be determined by applying a three-dimensional grid in combination with random sampling techniques as discussed in Section 3 of this document. Compositing of samples in certain circumstances may be acceptable to minimize the number of sample analyses, as long as the waste remains fairly constant over the sampling period. When the composition of the waste material is expected to vary (e.g., in complex wastes), grab samples should be taken. Compositing should only be employed when the representativeness of the waste characterization is uncompromised, and should always be accompanied by confirmational grab samples.

Bulk solid materials are generally homogeneous. They are likely to be found in waste piles, drums, bags, trucks or hoppers, or on conveyor belts. Bulk solid materials can be sampled using various methods. Surface soil or soil-like materials found at land treatment units, landfills and at waste transfer (e.g., loading and unloading) areas can also be sampled using the same basic methods. Deeper soil sampling will require other methods as described in Section 9 on soil.

Five basic solid sampling methods are discussed below:

- Scoops and shovels are useful for sampling dry or moist granular, powdered, or otherwise unconsolidated solids from piles as well as from other containers of solid material (e.g., bags, drums, hoppers, trucks, or shallow containers). Waste material that is transported to the unit by conveyor belt can be sampled using a scoop to collect samples from a moving or stationary conveyor belt. Scoops are applicable to solid waste material that are within easy reach of sampling personnel. Scoops made of stainless steel or Teflon are preferable due to the inertness of these materials to most waste types. This sampling method is limited in utility to collection of samples near or on the surface of the waste. For collection of samples at greater depth, other methods are necessary. Shovels are used in the same manner as scoops when larger quantities of sample are needed or when an extended reach is required. Shovels are available in inert materials like Teflon or stainless steel. Scoops and shovels will be able to collect land treatment unit samples from depths of up to about 16 inches. Since most land treatment units manage organic waste streams, extreme care must be taken to retain the volatile organic components of the sample through rapid handling of the exposed sample during the collection process. Containers that have septum caps or air-tight lids should be used in conjunction with the scoop and shovel sampling method. Collection of soil samples from depths lower than the normal depths of tilling are described in Section 9. Contaminated surface soils at waste transfer areas are also easily sampled using scoops and shovels.

- Triers are used to withdraw a core of sample material. The trier is similar to a scoop in that it is inserted by hand into the material to be sampled; however, the design allows for the collection of a core of material. Triers are most useful for sampling waste piles, bags, hoppers or other sources of loose solid waste material. Cores are most readily obtained with triers when the material being sampled is moist or sticky so that the core, which is cut by rotating the trier, stays together while the sample is removed from the waste material source. These samplers are only useful when they can be inserted horizontally into the material being sampled. Triers are readily available in lengths from 61 to 100 cm and are usually made of stainless steel with wooden handles.

- Thiefs are essentially long hollow tubes with evenly spaced openings along their lengths. An inner tube with similar openings is oriented so that the openings are not aligned and the entire dual tube thief is inserted into the solid waste material. After insertion, the inner tube is rotated to align the openings, thus allowing the solid material to flow into the inner tube. The inner tube is then rotated back to the closed position sealing the openings prior to withdrawal of the sampler. Thiefs can be inserted horizontally, vertically, or at various angles into the sample as long as the material will flow (by gravity) into the slots of the sampling tubes. This method is best suited for sampling of dry free-running solids. Thiefs are available in a range of sizes to allow for collection of materials of varying particle size, but are not generally useful for particles in excess of 0.6 cm. Thiefs, like triers, are available in a variety of materials, usually brass or stainless steel, and are appropriate for sampling waste piles, drums, or hoppers.

- Augers can be used to sample solid material at varying depths. The use of augers is generally exclusive to the collection of soil samples at depth such as at landfills. However, for large waste piles, that cannot be sampled in any other manner, it may be necessary to obtain samples from the inside portions of the pile in order to assess the overall characteristics of the material in the pile. Generally, augers are used in conjunction with a thin-wall tube sampler that is inserted into the bore hole to collect an undisturbed sample from the depth at which the auger was stopped. The nature of the solid material and the physical size and accessibility of the unit will determine the applicability of augering and the type of auger that is most suitable. Augers are designed for general types of soil conditions and "disturb" samples to varying degrees. If possible, sampling of waste material should be conducted prior to or during waste placement since sampling by augers and thin-wall tubes can be difficult and time consuming. Backhoes may be required to gain access to the interior portions of the unit (e.g., a waste pile).

- Core samplers such as previously described in conjunction with augers are frequently used for soil sampling. Section 9 addresses soil sampling in greater detail. Core samplers can also be used to collect cores of land treatment unit samples and provide excellent samples for spanning the depth of treated soil. Thin wall tube core samplers can be used to collect vertical cores at most desired locations. Sampling of top soil layers that contain the applied waste material can usually be accomplished using conventional hand coring techniques. As with the scoop and shovel method, extra consideration should be given to preventing losses of volatile organic components from the sample; the use of air-tight sample containers is recommended. Another technique is to utilize a core sampler which can itself be used as an air-tight sampling container. Recent designs include a coring device with Teflon-gasketed end caps that can be used to both collect and contain land treatment samples for soil and soil-gas analyses.

7.4.3 Sampling Sludges

Sludges are "semi-dry" materials ranging from dewatered solids to high viscosity liquids. Due to their liquid content, sludge materials are not usually stored or handled as solids, and often require containment in drums, tanks, or impoundments, to prevent runoff of the liquid portion of the sludge. Sludges also include sediments with high liquid content found under a liquid layer. Sampling must frequently include extended reach equipment to gain access to the submerged sludge layer. For those cases where sludges are piled and have a sufficiently high solids content, methods previously discussed under "Solids" may be adequate. The equipment used in some of the solid material sampling methods are available with modifications to contain samples with a high liquid content.

Sediments can accumulate at the bottom of drums due to settling of suspended solids in liquid and sludge wastes. These sediments can be readily sampled using the previously discussed methodology. Glass tube samplers, particularly those of larger bore, can be pressed into bottom sediments of drums to obtain samples. For bottom sediments or sludges that are too thick or resistive for glass tubes, corers with or without core catchers can be inserted into the drum for collection of sediments.

Basic methods for sampling sludges are discussed below:

- Scoops and shovels are useful for collecting sludge samples from the surface of a sludge pile, or at shallow depths in drums, tanks, or surface impoundments. Shovels will allow for the collection of larger volume samples. Extra care may be required to collect "representative" samples if the liquid fraction of the sludge tends to separate from the sample while being collected. The liquid fraction should be considered part of the sludge material and must be retained for adequate characterization. Long sleeve gloves may be required for personnel protection.

- Triers may be useful for collection of cores of material from sludge piles. The nature of the waste will determine the utility of this method. Triers are not generally used for sludges; however, on a trial and error basis, their applicability may be determined.

- Core samplers modified to retain sludge material can be used to collect sludge from waste piles where samples are required from various depths. Core catchers such as thin-wall tube samplers that prevent washout of the wet sludge during recovery of the sampler from the sludge source, are available for attachment to the tip of coring devices. Since sludges are most often formed through deposition of solids from a liquid mixture, the composition of the sludge may vary significantly with regard to time and location. The use of a core sampler equipped with a core catcher can provide for collection of a sample profile. These types of corers are available with extension sections that allow for collection of samples from depths well below the surface of the waste. Corers are generally equipped with a cutting edge on the tip that greatly facilitates penetration of a thick bottom layer and can also be outfitted with core catchers to assist in retaining looser sediment materials that might be more readily lost from the bottom of a glass tube. The amount of sludge present can be easily estimated by measuring the depth to the apparent bottom and comparing it to the known interior depth.

- Glass tubes or a COLIWASA (Composite Liquid Waste Sampler) can collect bottom sediments from drums or shallow tanks by gradually inserting them into the solid layer at the bottom. Due to the fragility of glass and the danger of cuts, this technique is only applicable for materials that are easily penetrated by the tube. High liquid content bottom sediments may exhibit similar washout characteristics as liquid samples. In many cases, the only way to determine if sample losses from the bottom of the tube will occur is to carefully test it to see what happens.

- Petite Ponar Grab Samplers are clamshell type scoops activated by a counter lever system. The shell is opened and latched in place, then lowered to the bottom. When tension on the sample line is released, the shell halves are unlatched. The lifting action of the cable on the lever system closes the clamshell. These dredges are capable of collecting most types of sludges or sediments from silts to granular materials up to a few centimeters in diameter. Agitation of the liquid above the sludge does occur during sampling; therefore, it is advisable to collect sediment samples after all liquid sampling is complete. This method is particularly useful for tanks and surface impoundments.

7.4.4 Sampling Liquids

Liquid wastes require distinctly different sampling methods from solids and sludges, with the exception of some techniques for sampling submerged sediments, and should also account for parameters of interest (e.g., for volatile contaminants, it is important to prevent volatilization). The common liquid waste sources are drum handling units, tanks, and surface impoundments. A general safety concern associated with drums and tanks is the structural integrity. Safe access procedures for sampling these units should be established prior to sample acquisition.

Liquid wastes handled in drums can be sampled before being loaded into the drum or, if necessary, after placement. For facilities that receive wastes in drums, sampling should be conducted prior to the removal of the waste material from the drum. For waste streams that can be sampled directly prior to drum loading, grab sampling techniques are appropriate. As always, sufficient samples should be collected to account for waste variation over time. Sampling of drums can be done using several different methods, including grab sampling with a dipper from the open drum, routine full depth drum sampling using a disposable glass tube or COLIWASA, or with a sampling pump method with tubing that is lowered into the drum for sampling.

Tanks are containment structures larger than drums that can hold up to more than a million gallons. Tanks include tanker trucks, above-ground tanks and partially or fully underground tanks. Tanks usually have limited access due to small hatchway openings, ladders or walkways that often extend across open-top tanks.

Due to the greater depth of tanks versus drums, methods with extended reach capabilities are necessary. Waste materials contained in tanks generally include liquids and bottom sludges. When retention time of liquid wastes in tanks is long, layering or stratification including settling out of sediments is likely to occur. Great care should be taken to minimize the disturbance of liquid layers while collecting samples. The surface should be broken gently and samplers lowered gradually. Liquid sampling utilizes either pump and tubing methods or discrete depth samplers, such as Kemmerer Bottles or Bacon Bomb samplers. Bottom sediments that cannot be drawn up with a pump will require the use of small dredges, such as the Petite Ponar Grab sampler.

Surface impoundments can range in size from several hundred to several million gallons in capacity. Due to their large size, they are usually open to the atmosphere rather than covered . Sampling of an impoundment may be difficult, except near its edges or from walkways that extend over the impoundment. "Off- shore" sampling, when necessary, should be considered a serious, potentially dangerous operation and should be performed according to strict health and safety procedures. Common means of sampling off-shore locations are boats, floating platforms, cranes with suspended enclosed platforms, and mobile boom vehicles with platforms.

Whenever possible, the waste should be characterized prior to its transfer into the impoundment. For example, waste pipelines can be sampled from valves, and tanker trucks discharging waste into impoundments can be sampled prior to the discharge. However, taking samples from the units is desirable, since changes in the concentrations reported for samples taken during transfer may have large impacts on the estimates of the amounts of hazardous waste or constituents in the impoundment.

Liquid sampling techniques for impoundments include Dippers (particularly in the pond sampler configuration with a telescoping handle), pump and tubing, Kemmerer bottles, and Bacon bomb samplers. The dipper or pond sampler method is the easiest to use; however, it is not capable of reaching off-shore locations or for collecting samples at varying depths below the surface.

Liquid sampling methods are described below:

- Dippers can be used to collect samples from the surface liquid layer of open drums, tanks, or impoundments. Other techniques are required to collect samples from drums where the only access is through the bung hole in the lid. This method is appropriate only for wastes that are homogeneous and likely to be represented by a grab sample from the top layer. In most cases, a full depth composite liquid sample is more representative. The dipper technique involves the use of an intermediate vessel that is submerged in the waste liquid. The sample is then poured into the designated sample container. Handles are attached to the vessel to make sampling easier and reduce direct contact of the sampling technician with the waste material. In one configuration, the dipper is attached to a telescoping pole for an extended reach; this configuration is called a pond sampler. The dipper sampling device is also useful for sampling from piping system valves.

- Glass tube samplers can collect a full depth liquid sample from a drum and can be used through the bung hole on the drum lid such that the lid need not be removed. Conventionally, the glass tubes are 122 cm long and 6 to 16 mm inside diameter. Larger diameter tubes can be used if the liquid to be sampled is more viscous. The major limitation of this method is spillage (i.e., liquid loss from the bottom of the tube is unavoidable). Smaller diameter tubes have fewer problems with sample loss than large bore tubing. This method is perhaps the most common drum sampling technique in use due its relative ease and the minimal equipment decontamination required.

- COLIWASA samplers are a more formalized version of the glass tube samplers. The COLIWASA (composite liquid waste sampler) utilizes an inner rod that is attached to a stopper at the bottom of the sampling tube. The sampler is slowly inserted into the drum with the bottom stopper open. When the sampler reaches the bottom, the inner rod is pulled up, sealing the sampling tube for removal of the sample. A COLIWASA can be made of many materials; however, inert materials (e.g., Teflon or glass) are the materials of choice.

- Pump and tubing (e.g., bladder pumps) systems are readily available and are useful for withdrawing liquid samples from up to 28 feet in depth. Peristaltic pumps are available in many sizes and flow rates to accommodate many sampling situations. Full depth composite samples can be collected by gradually lowering the tubing into the material being sampled. One limitation of this system is that the pump applies a vacuum to the sample that can alter the chemical equilibrium in the sample, resulting in the loss of volatile organic components. A modification to this basic system can be made by placing a sample vessel in-line between the tubing and the pump to prevent sample material from contacting the pump parts. In this configuration, collection of numerous samples is facilitated since pump tubing need not be cleaned or replaced between sampling events.

  High flow rates are not advisable since rapid overflowing of sample bottles may occur. A lower flow rate will assist in minimizing the disturbance of liquid layers in the tank and will cause less agitation of the sample as it enters the sample bottle. The peristaltic pump and tubing system can be utilized in two configurations -- one with the tubing connected directly to the pump and a second with an intermediary sample vessel in-line between the pump and tubing. The second configuration also eliminates pump decontamination between samples. When sufficient waste characterization data are available, small submersible pumps can also be used; however, these pumps are not generally made of materials that are chemically resistant or relatively inert. The utility of these small submersibles depends upon their ability to provide samples from greater depths. Peristaltic pumps have an upper limit of approximately 8 meters, whereas submersibles can be used for most depths of concern.

- Kemmerer Bottles are discrete-depth liquid samplers that are usually appropriate for tank or impoundment sampling. The Kemmerer Bottle is a spring loaded device that is lowered into the liquid in the open position, allowing the liquid sample to flow through it while it is descending. At the desired depth, a messenger is dropped down the sample line, releasing the spring loaded closing device to obtain the sample. Limitations of Kemmerer Bottles include the poor availability of devices constructed of relatively inert materials, the difficulty in decontamination between sampling, and the inability of this sampler to collect purely depth-discrete samples (since the sampler's surfaces are exposed to materials in the liquid layers as it passes through them to arrive at the designated depth).

- Bacon Bomb samplers are lowered on a sample line. A second line attached to an opening rod, which runs down the center of the bomb, will open the sampler when pulled. The sample can be collected with a minimal amount of agitation since the rod can open the top and bottom of the bomb, allowing the sample to enter the bottom and air to exit through the top. Bacon Bomb samplers are readily available from laboratory supply houses and are frequently constructed of chrome- plated brass. Relatively inert construction materials, such as Teflon or stainless steel, are preferable. Careful maintenance and regular inspection of samplers is advised. Samplers with plating materials flaking off should be removed from use. If waste characteristics are known, sample changes caused by the sampler can be avoided by using materials compatible with the type of waste being sampled. An advantage of the Bacon Bomb sampler is its ability to be lowered to the desired depth in the closed position before collecting a sample. This technique minimizes cross-contamination from liquid layers above.

SECTION 8
HEALTH AND ENVIRONMENTAL ASSESSMENT

8.1 Overview

This section describes the Health and Environmental Assessment (HEA) that will be conducted by the regulatory agency as part of the RFI. The primary element of this assessment is a set of health and environmental criteria (chemical concentrations) to which measured and in some cases predicted (e.g., for the air medium) concentrations of hazardous constituents developed during the release characterization will be compared. When these criteria are exceeded or there is a reasonable likelihood of this occurring, a Corrective Measures Study may be required. This section describes the HEA process (Section 8.2), the determination of potential exposure routes for each environmental medium of concern (Section 8.3), and the development and use of the health and environmental criteria (Section 8.4), leading to an evaluation of the need for appropriate interim corrective measures and/or a Corrective Measures Study. The evaluation of chemical mixtures is discussed in Section 8.5. Special considerations involved in the evaluation of deep soil and sediment contamination are discussed in Section 8.6. Section 8.7 discusses qualitative factors which may be used by the regulatory agency in conducting the health and environmental assessment. Interim corrective measures are discussed in Section 8.8. References used in developing this section are listed in Section 8.9. Finally, Section 8.10 presents the health and environmental criteria and provides several worksheets which may be used to conduct the HEA.

The health and environmental criteria used in determining the need for a Corrective Measures Study are based on EPA-established chronic-exposure limits. These values and their use are described herein. Qualitative criteria are also discussed. The alternative of also basing decision criteria on subchronic exposure limits is currently being evaluated and may be applied in future editions of this guidance.

It should be emphasized that the existing health and environmental criteria provided in this section do not necessarily represent clean-up target levels that must be achieved through the implementation of corrective measures. Rather, they establish presumptive levels that indicate that a closer examination is necessary. This closer analysis would generally take place as part of a corrective measures study. Separate guidance is currently being developed for use in performing a corrective measures study. This document will examine standards for determining whether, and if so, what corrective measures are necessary. It will provide guidance for evaluating various corrective measure alternatives and establishing site-specific clean-up levels. These evaluations will address the technical feasibility of clean-up levels, resource value of the contaminated media, and hazards associated with corrective measures. The document will provide guidance on determining whether no action is necessary, and on establishing media clean-up standards based on the type of demonstrations undertaken for alternate concentration levels in 40 CFR Subpart F.

The guidance provided in this section presents a general framework for conducting a HEA. It is intended to provide a flexible approach for interpreting release characterization data, as case-specific factors may enter into consideration. For example, State-generated criteria and consideration of past environmental problems (e.g., fish-kills) may also be considered.

The regulatory agency may require both interim corrective measures and a Corrective Measures Study as a result of the HEA. One difference between interim corrective measures and definitive corrective measures may be timing. The development and implementation of a comprehensive corrective action program can be a time-consuming process. Between the time of the identification of a contaminant release and the implementation and completion of corrective measures, existing conditions or further contaminant migration can endanger human health and the environment. Under these conditions, interim corrective measures, which may be temporary or short-term measures (e.g., providing bottled water or removing drums) designed to prevent or minimize adverse exposure, can be applied. Case Study No. 12 in Volume IV (Case Study Examples) provides an illustration of the Health and Environmental Assessment process.

The HEA procedures described in this section apply to releases from all units except releases to ground water from "regulated units" as defined under 40 CFR Part 264.90(a)(2). Releases to ground water from "regulated units" must be addressed according to the requirements of 40 CFR §264.91 through §264.100 for purposes of detection, characterization, and appropriate response.

8.2 Health and Environmental Assessment Process

The HEA is a continuous process that begins with the initiation of the RFI. As investigation data (from monitoring and/or modeling) become available, both within and at the conclusion of discrete phases, they should be reported to the regulatory agency. The regulatory agency will compare these data to applicable health and environmental criteria, including qualitative criteria, to determine the need for (1) interim corrective measures; and (2) a Corrective Measures Study. Notwithstanding this process, the owner or operator has a continuing responsibility to identify and respond to emergency situations and to define priority situations that may warrant interim corrective measures. For these situations, the owner or operator should follow the RCRA Contingency Plan required under 40 CFR Part 264, Subpart D and Part 265, Subpart D.

The results of the media-specific investigations described in Volumes II and III of this Guidance will be used to identify the constituents of concern, constituent concentrations within the release, general release characteristics (e.g., organic, inorganic), the affected environmental media, exposed or potentially exposed human or environmental populations, the rate of migration of the release, and the extent of the release. The objective of the HEA is to integrate these results to determine whether interim corrective measures and/or a Corrective Measures Study may be necessary. In general, this objective is achieved in a two-step process.

First, potential human and environmental exposure routes are determined at actual or potential receptor locations for constituents in the release. Section 8.3 provides guidance for determining potential exposure routes for the media of concern. For ground water, surface water, soil, and air, methods are described for making exposure route-specific comparisons with the health and environmental criteria. Subsurface gas migration and inter-media transport of contamination from other media to air (e.g., ground-water contamination resulting in basement seepage of volatile constituents) are addressed as air problems to the extent that they contribute hazardous constituents to ambient air, whether indoors or outdoors. Evaluation of the migration of methane gas in the subsurface is also addressed in this section (Section 8.8) as part of the guidance on interim corrective measures, due to the immediate explosion potential of methane.

Second, the measured (or in some cases, predicted) constituent concentrations in the release are compared to EPA-established exposure-limit criteria. At any time during the RFI when contaminant concentrations in the release are found to exceed the health and environmental criteria, a Corrective Measures Study may be required by the regulatory agency, and the need for appropriate interim corrective measures should be determined. This latter process involves an evaluation of exposed or potentially exposed human and environmental populations. This process is discussed in more detail in Section 8.8.

The determination of whether a Corrective Measures Study may be necessary will be made by the regulatory agency by comparing constituent concentrations determined at locations within the release to the health and environmental criteria discussed in Section 8.4. These criteria serve as "action levels" for determining whether a Corrective Measures Study may be necessary. Figure 8-1 depicts a hypothetical facility with individual solid waste management units and a contaminant release originating from one of the units. For ground water, surface water, soil and subsurface gas, the comparison of constituent concentrations with the criteria will be made for all measurements within the release at and beyond the limit of the waste management area.

The evaluation procedure for releases to air differs from the other media in that the comparison of constituent concentrations with the health and environmental criteria will be made at actual points of exposure. In general, the comparisons will be made at receptor locations expected to receive the highest constituent concentrations and which are at or beyond the facility property boundary. However, onsite comparisons may be necessary in cases where people reside at the facility or when worker safety regulations are not adequate. As indicated in the Air Section (Section 12), the values compared can be either measured values derived from monitoring or predicted values derived from modeling.

8.3 Determination of Exposure Routes

Some of the more significant potential exposure routes for each environmental medium are presented in Table 8-1. This Table should be used to determine the appropriate health and environmental criteria to be used in the comparison with measured or predicted constituent release concentrations. For example, when releases to ground water have been identified, the primary exposure route of concern is the ingestion of drinking water. For each constituent identified in the ground-water release, the measured concentrations are compared with the appropriate criterion values discussed for drinking water in Section 8.4.

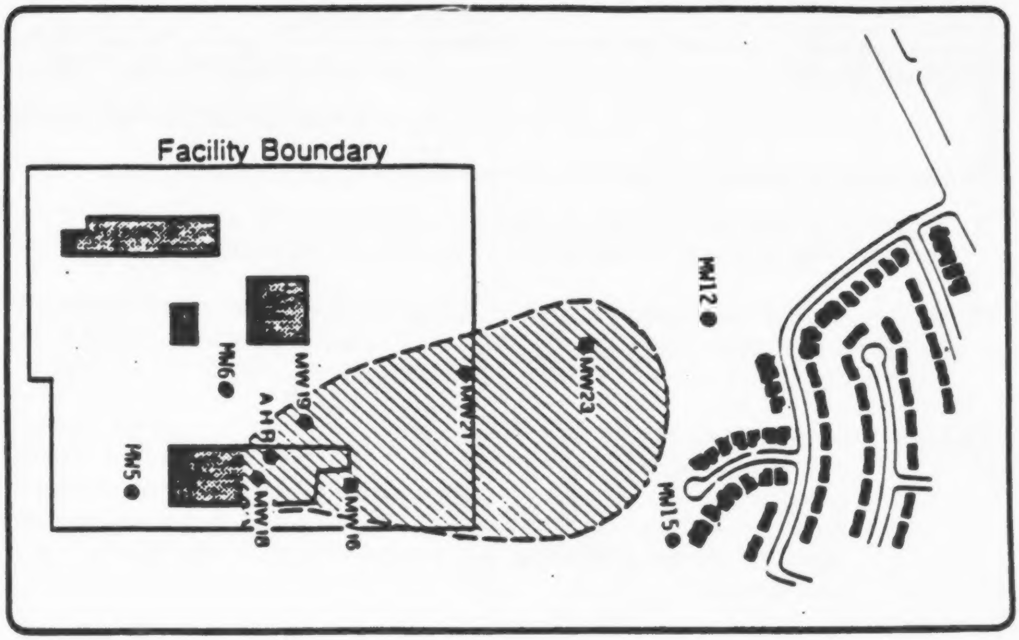

Facility Boundary
MW12
MW23
MW21
MW19
MW6
AHR
MW5
MW18
MW16
MW15

FIGURE 8-1. **Hypothetical facility with individual solid waste management units and a contaminant release originating from one of the units. (● denotes sampling locations)**

TABLE 8-1

Some Potential Exposure Routes

Contaminated Medium	Exposure Route
Soil[1]	Soil-Ingestion (surficial soil), Dermal Contact
Ground Water	Ingestion of Drinking Water
Subsurface Gas[2]	Inhalation
Air	Inhalation
Surface Water[1]	Ingestion of Drinking Water Consumption of Contaminated Biota (e.g., fish)

1 Exposure routes for deep contaminated soils and bottom sediments underlying surface water bodies are addressed separately in Section 8.6

2 Migration of methane gas in the subsurface presents a problem due to the explosive properties of methane. This is treated as an immediate hazard and is discussed under interim corrective measures (Section 8.8).

[Note: Other important exposure pathways can include inhalation of volatile constituents released during domestic use of contaminated ground water or when such ground water seeps into residential basements. Similarly, there are various exposure pathways that can lead to adverse effects on environmental receptors (i.e., animals and plants).]

Suspected inter-media transfers of contamination should have been characterized (i.e., nature, extent and rate) during the RFI process. For example, if the initial contaminant release was to the soil medium and eroded soils have been transported to surface water, both soil and surface water contamination should have been adequately characterized during the RFI. In this example, the regulatory agency will consider exposure in both media. In cases where subsurface gas, soil, or ground-water releases have caused basement seepage, inter-media transfer to the air may pose an inhalation hazard. In such cases, contamination of basement areas should have been adequately characterized during the investigation.

8.4 Health and Environmental Criteria

The preliminary set of health and environmental criteria are presented in Tables 8-5 through 8-8 in Section 8.10. The constituents shown in Tables 8-5 through 8-8 are a subset of the hazardous constituents listed in Appendix VIII of 40 CFR Part 261. The concentrations shown for each constituent are derived from EPA-established chronic (and in some cases acute) toxicity criteria for ingestion (soil and drinking water) or inhalation exposure routes, and were calculated using a set of intake assumptions for the various media, as shown in Table 8-2. As indicated in the footnotes accompanying Tables 8-5 through 8-8, the criteria presented are subject to change. Therefore, these numbers should be confirmed prior to their use.

8.4.1 Derivation of Health and Environmental Criteria

Maximum Contaminant Levels (MCLs) -- Table 8-5 provides the maximum contaminant levels (MCLs) established for drinking water promulgated under the Safe Drinking Water Act. In developing these values, total environmental exposure to a particular contaminant from various sources (e.g., air, food, water) and gastrointestinal absorption were considered. The process of considering exposure from various sources in developing these levels is referred to as apportionment. For example, based on an exposure assessment, EPA may assume that a portion of the total exposure comes from other sources, such as food (e.g., pesticide residues) or air (e.g., lead from automobile exhaust).

TABLE 8-2

Intake Assumptions for Selected Routes of Exposure

Surficial Soils (Ingestion): 0.2 g/day for 70 kg person/70 year exposure period for carcinogens 1.0 g/day for a 17 kg child/5-year exposure period for systemic toxicants*
Surface and Ground Water (Ingestion): 2 liters/day for 70 kg adult/70-year exposure period
Air (Inhalation): 20 m^3 air/day for 70 kg adult/70-year exposure period

* Corresponds to the period of 1 to 6 years of age.

The MCL, when available for a constituent released to ground water or surface water, should be used as the evaluation criterion for human drinking water consumption for that constituent. If an MCL does not yet exist for a particular constituent, criteria in the other tables presented in Section 8.10 should be used, where available. If air, surficial soil, or sediment (See Section 8.6) are the media of concern, or when evaluating aquatic life exposure or human consumption of aquatic organisms, the MCL is not used. In this case the criteria in the other tables should be used, as described below.

Carcinogens -- Table 8-6 presents the human health-based criteria for carcinogens. These criteria, known as Risk-Specific Doses (RSDs), were developed according to EPA Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1986). The values presented are environmental concentrations that, under the intake assumptions shown in Table 8-2, correspond to excess lifetime cancer risks of 10^{-6} for Class A and B carcinogens, or 10^{-5} for Class C carcinogens. Table 8-6 presents the class (A, B or C) of the carcinogen. (See U.S. EPA, 1986, for a description of carcinogen classification).

The RSD concentrations presented in Table 8-6 were calculated in the following manner:

$$RSD = (R/q_1^*) \times (W/I) \qquad \text{(Equation 8-1)}$$

where:

R = the specified risk level (e.g., 10^{-6});

q_1^* = the carcinogen potency factor CPF in $(\text{mg/kg/day})^{-1}$ developed by the Carcinogen Assessment Group (CAG) of the U.S. EPA, Office of Health and Environmental Assessment;

I = the intake amount for a given time period; and

W = the assumed wieght of the exposed individual.

For example, the health-based criterion (RSD) for aldrin, a Class A carcinogen, was calculated for water in the following manner:

$$\begin{aligned} \text{RSD} &= (R/q_1{}^*) \times (W/I) \\ &= (10^{-6}/1.7\text{E} + 01\ (\text{mg/kg/day})^{-1} \times (70\ \text{kg}/2\text{l/day}) \\ &= 2.1 \text{ X } 10^{-6}\ \text{mg/liter} \\ &= 2.1 \text{ X } 10^{-3}\ \mu\text{g/liter} \end{aligned}$$

Calculation of the RSDs for soil ingestion and air inhalation shown in Table 8-6 takes essentially the same form. However, the values for the assumed intake rate (I) differ. The assumed intake rate for soil that is used in the calculations for carcinogens is 0.2 g/day for a 70 kg person. Because the expression of carcinogenic effects is principally a function of cumulative dose (i.e., the time course of exposure is usually secondary), elevated exposures during early childhood (ages 1-6) are relatively unimportant in determining cancer risk. Therefore, the soil intake value of 0.2 g/day is a reasonable worst case estimate of total lifetime (cumulative) ingestion normalized for a per day value. It is derived by averaging reasonable worst case estimates of total soil intake for young children (1 g/day for 5 years) and for older children and adults (0.1 g/day for 65 years). The intake rate (I) for air inhalation is 20 m^3/day for a 70 kg person.

Many of the health-based criteria for carcinogens shown in Table 8-6 are below current analytical detection limits (See Section 3.6 for a discussion of detection limits). For example, the concentration for dieldrin in Table 8-6 is 2.2 X 10^{-3} µg/l for the drinking water exposure route, while the corresponding limit of detection for this constituent is approximately 5 X 10^{-2} µg/l. In those cases where the criterion is less than the limit of detection, the detection limit will be used as a default value when making comparisons to investigation data, unless acceptably determined modeling values can be applied (i.e., values from air dispersion models).

The RSDs provided in Table 8-6 address the surficial soil (ingestion), water (ingestion), and air (inhalation) routes of exposure. For human health assessment, the RSD criteria for water should be used when ground water or surface water is the medium of concern, unless MCLs or lower reference doses exist. The RSD criteria for surficial soil (ingestion) and air (inhalation) should be used if surficial soil or air, respectively, is the medium of concern, unless a lower value appears in Table 8-7. If a particular constituent is not identified in Table 8-6, the criteria in Table 8-7 (systemic toxicants) should be used. As alluded to above, constituents that are both known carcinogens and systemic toxicants (e.g., chloroform) will have values in both Tables 8-6 and 8-7. In such cases, the lower of the two values should be used as the action level. Both values are presented in the Tables if needed for determining the additive toxicity of mixtures (See Section 8.5).

Systemic Toxicants -- Table 8-7 presents the human health-based criteria for systemic toxicants. These criteria, known as Reference Doses (RfDs) are an estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. For water ingestion the RfD was calculated for a 70 kg adult for a chronic lifetime exposure period (i.e., 70 years). For soil ingestion, the assumed intake rate of 1g/day is based on a 5 year exposure period for a 17 kg child. These exposure assumptions for soil are reflective of a reasonable worst case scenario in which children ages 1-6 (who exhibit the greatest tendency to ingest soil) are assumed to ingest an above-average amount of soil on a daily basis. The concentrations shown in Table 8-7 were calculated using the intake assumptions presented in Table 8-2 for the selected exposure routes, as shown in the following equation:

$$C_i = (\mathrm{RfD}) \times (W/I) \qquad \text{(Equation 8-2)}$$

For example, the concentration (C_i) for surface water and ground water for pentachlorobenzene shown in Table 8-7 was calculated in the following manner:

C_i = Criterion concentration for constituent of interest

RfD = Reference Dose for pentachlorobenzene

= 8×10^{-4} mg/kg/day

I = ingestion rate (from Table 8-2)

= $\frac{2 \text{ liters}}{\text{day}}$

W = adult body weight (from Table 8-2)

= 70 kg

C_i = $(8\times10^{-4}$ mg/kg/day) x (70 kg/2 l/day)

= 2.8×10^{-2} mg/liter

C_i = 2.8×10^{1} µg/liter (which rounds off to 3×10^{1} µg/liter)

As with the carcinogen criteria, some of the RfDs presented in Table 8-7 may be below current analytical detection limits (See Section 3.6 for a discussion of detection limits). In those cases where the criterion is less than the limit of detection, the detection limit will be used as a default value when making comparisons to investigation data, unless acceptably determined modeling values can be applied (i.e., values from air dispersion models).

EPA is in the process of developing inhalation criteria for systemic toxicants based on inhalation toxicity studies. When these criteria are developed, they will be incorporated into the IRIS data base (see Section 8.4.2).

The RfDs for the water (ingestion) route of exposure should be used unless MCLs or lower RSDs exist. For other routes of exposure (e.g., soil ingestion) RSDs should be used unless lower RfDs exist. As indicated previously, some toxicants are both carcinogenic and systemically toxic (e.g., chloroform) and, thus, appear in both Tables 8-6 and 8-7. In such cases, the lower of the RSD or RfD criterion should be used.

Water Quality Criteria -- A summary of the EPA Water Quality Criteria (WQC) appears in Table 8-8. These criteria exist to protect both marine and fresh water aquatic life and address both acute and chronic toxicity. WQC also exist for protection of human health through water and fish consumption (incorporating both routes of exposure), and for fish consumption only. If human consumption of both the surface water and contaminated aquatic organisms is a factor, the set of criterion values based on ingestion of contaminated aquatic organisms and drinking water should be used. The values based on consumption of fish alone should be used only when human consumption of the surface water is not of concern. WQC should only be used when surface water is the medium of concern. If aquatic life exposure and human exposure are both of concern, the more stringent criterion should be used.

8.4.2 Use of Criterion Values

Additional guidance on the use of the health and environmental criteria and the overall HEA process is presented below.

As indicated previously, the criteria presented in Tables 8-5 through 8-8 are subject to change. In addition, these tables do not present levels for all of the 40 CFR Part 261, Appendix VIII constituents. As existing health effects data are reviewed and more information becomes available from laboratory and epidemiological studies, these tables may be expanded to include additional hazardous constituents.

Current information on the health and environmental effects of various toxicants, including information on criteria values (e.g., RSDs and RfDs) and supporting toxicological studies, may be obtained from review of the following document:

> U.S. EPA. 1987. Integrated Risk Information System (IRIS) Chemical Files. EPA/600/8-86/032b. Office of Health and Environmental Assessment, Office of Research and Development. Washington, D.C. 20460.

The Integrated Risk Information System (IRIS), is a computerized library of current information that is up-dated on a continuous basis. It contains health risk assessment information on chemicals which have undergone a detailed review of toxicity data by work groups composed of U.S. EPA scientists from several Agency program offices, and represent EPA consensus. IRIS may be accessed by the EPA Regions through the electronic mail system. Public inquiries on the availability of IRIS may be made to EPA's Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, in Cincinnati Ohio ((513) 569-7254). IRIS will soon be available to the general public.

If EPA has not yet developed criteria for constituents which may be pertinent to a particular release, there are various options which may be exercised by the regulatory agency. A literature search may be performed to locate any health effects data which can be used to develop an interim criterion value or at least, information such as type of health effect (e.g., carcinogens) which can be used to make judgments. The regulatory agency, for example, may obtain and review EPA summaries of health and environmental effects produced for a particular constituent. These summaries include Health and Environmental Effects Profiles (HEEPs), Health Effects Assessment (HEA) documents, and other documents produced by EPA to summarize health and environmental effects for particular constituents. These documents are collectively known as Health and Environmental Effects Documents (HEEDs), and are available for many of the 40 CFR Part 261 Appendix VIII constituents through EPA's RCRA Docket and library, located at EPA Headquarters in Washington, D.C. A listing of all the HEEDs currently available is contained in the following document, which is also available through EPA's RCRA Docket and library:

> U.S. EPA, 1987. Background Document, Resource Conservation and Recovery Act, Subtitle C -- Identification and Listing of Hazardous Waste, Appendix A -- Health and Environmental Effects Documents. Office of Solid Waste. Washington, D.C. 20460.

Additionally, the HEA documents can be obtained from the National Technical Information Service (NTIS). Table 8-3 presents a list of all chemicals for which HEAs are available, and also identifies the NTIS ordering number.

If little or no useful information regarding a particular constituent can be located, the initiation of a toxicity bioassay may be considered. The Technical Assessment Branch, Health Assessment Section of the Office of Solid Waste, located in Washington, D.C., may be contacted for toxicological information ((202)382-4761). This office may also be contacted to determine whether a toxicity bioassay for a particular constituent is planned or is in progress. Comparison of background concentrations (as action levels) to constituent concentrations in the release may be

TABLE 8-3

CHEMICAL AND CHEMICAL GROUPS HAVING EPA HEALTH EFFECTS ASSESSMENT (HEA) DOCUMENTS[1]

CHEMICAL	NTIS[2] PB NUMBER
Acetone	86 134277/AS
Arsenic and Compounds	86 134319/AS
Asbestos	86 134608/AS
Barium and Compounds	86 134327/AS
Benzene	86 134483/AS
Benzo (a) pyrene	86 134335/AS
Cadmium and Compounds	86 134491/AS
Carbon Tetrachloride	86 134509/AS
Chlordane	86 134343/AS
Chlorobenzene	86 134517/AS
Chloroform	86 134210/AS
Chromium III and Compounds	86 134467/AS
Chromium VI and Compounds	86 134301/AS
Coal Tars	86 134350/AS
Copper and Compounds	86 134368/AS
Cresol	86 134616/AS
Cyanides	86 134228/AS
DDT	86 134376/AS
1,1-Dichloroethane	86 134384/AS
1,2-Dichloroethane (EDC)	86 134137/AS
1,1-Dichloroethylene	86 134624/AS
1,2-cis-Dichloroethylene	86 134269/AS
1,2-trans-Dichloroethylene	86 134525/AS
Dichloromethane	86 134392/AS
Ethylbenzene	86 134194/AS
Glycol Ethers	86 134632/AS
Hexachlorobenzene	86 134285/AS
Hexachlorobutadiene	86 134640/AS
Hexachlorocyclopentadiene	86 134129/AS
gamma-Hexachlorocyclohexane (Lindane)	86 134673/AS
Iron and Compounds	86 134657/AS
Lead and Compounds (Inorganic)	86 134665/AS

TABLE 8-3 (Continued)

CHEMICAL AND CHEMICAL GROUPS HAVING EPA HEALTH EFFECTS ASSESSMENT (HEA) DOCUMENTS[1]

CHEMICAL	NTIS[2] PB NUMBER
Manganese and Compounds	86 134681/AS
Mercury	86 134533/AS
Methyl Ethyl Ketone	86 134145/AS
Naphthalene	86 134251/AS
Nickel and Compounds	86 134293/AS
Pentachlorophenol	86 134541/AS
Phenanthrene	86 134400/AS
Phenol	86 134186/AS
Polychlorinated Biphenyls (PCBs)	86 134152/AS
Polynuclear Aromatic Hydrocarbons	86 134244/AS
Pyrene	86 134418/AS
Selenium and Compounds	86 134699/AS
Sodium Cyanide	86 134236/AS
Sulfuric Acid	86 134426/AS
2,3,7,8-TCDD (Dioxin)	86 134558/AS
1,1,2,2-Tetrachloroethane	86 134434/AS
Tetrachloroethylene	86 134202/AS
Toluene	86 134442/AS
1,1,1-Trichloroethane	86 134160/AS
1,1,2-Trichloroethane	86 134566/AS
Trichloroethylene	86 134574/AS
2,4,5-Trichlorophenol	86 134459/AS
2,4,6-Trichlorophenol	86 134582/AS
Vinyl Chloride	86 134475/AS
Xylene	86 134178/AS
Zinc and Compounds	86 134590/AS
Complete Set of 58 HEAs	86 134111/AS

[1] As of the date of publication for this guidance document.

[2] National Technical Information Service.

made by the regulatory agency when health and environmental effects information is not available.

Note also that the criteria presented in Tables 8-5 through 8-8 do not address all routes of exposure or forms of toxicity which may be of concern in particular circumstances. For example, dermal toxicity (absorption of toxicants through the skin) may also be of concern in particular cases. Phytoxicity (toxicity to plants) and other forms of environmental toxicity, such as terrestial toxicity (toxicity to animals and birds) may also be of concern. Additional information regarding other routes of exposure and forms of toxicity may be obtained from the following reference:

> U.S. EPA. October, 1986. Superfund Public Health Evaluation Manual. EPA 540/1-68/060. NTIS PB87-183125. OSWER Director No. 9285.4-1. Office of Emergency and Remedial Response. Washington, D.C. 20460.

Worksheet 8-1 in Section 8.10 may be used to present release characterization data and to facilitate the comparison of constituent concentrations to health and environmental criteria. Additional worksheets are provided for evaluating hazards posed by mixtures of constituents. Evaluation of chemical mixtures is discussed in the following section.

8.5 Evaluation of Chemical Mixtures

There are several situations when the overall potential for adverse effects posed by multiple constituents may be assessed. For example, if no individual constituent exceeds its action level in a given medium, but there are many constituents present in the medium, the overall (additive) health risk may be assessed to determine whether a Corrective Measures Study may be required. In other cases, an evaluation of the health risk posed by a mixture of constituents may be used in assessing the need for interim measures, particularly where exposure is actually occurring. The Guidelines for the Health Risk Assessment of Chemical Mixtures (U.S. EPA, 1986) describe the recommended approach to be used in evaluating the chronic effects of exposure to a chemical mixture. According to the guidelines, a mixture is defined as "any concentration of two or more chemicals regardless of source or of spatial or temporal proximity." Under these guidelines, additivity of effects for carcinogens can be assumed. The guidelines also allow for additivity of systemically toxic constituents which cause similar systemic effects. Carcinogens and systemic toxicants must be evaluated separately. When evaluating mixtures of systemic toxicants, constituents should be grouped by the same mode of toxicological action (i.e., those which induce the same toxicological endpoint, such as liver toxicity).

The overall risk posed by a mixture of constituents is evaluated through the use of a Hazard Index (HI) that is generated for each health endpoint. For systemic toxicants, the hazard index (HI_T) takes the form:

$$HI_T = \sum_{i=1}^{n} \frac{E_i}{AL_i} \qquad \text{(Equation 8-3)}$$

where:

E_i = exposure level of the ith toxicant

AL_i = maximum acceptable level for the ith toxicant

n = total number of toxicants

The hazard index for carcinogens (HI_c) is similar:

$$HI_c = \sum_{i=1}^{n} \frac{E_j}{DR_j} \qquad \text{(Equation 8-4)}$$

where:

E_j = exposure level to the jth carcinogen

DR_j = dose at a set level of risk for the jth carcinogen

n = total number of carcinogens

If any calculated hazard index exceeds unity (i.e., one), then the need for interim corrective measures and/or a Corrective Measures Study may be assessed.

The use of the hazard index in the evaluation of chemical mixtures is described below for an example case in which three carcinogens were measured within a contaminant release. Trichloroethylene and carbon tetrachloride levels in the ground water were measured at 2 and 0.1 µg/l, respectively. A breakdown product of carbon tetrachloride, chloroform, was also measured at a level of 3 µg/l. None of these concentrations exceed the individual criteria presented in Tables 8-5 through 8-8. (The RSDs for trichloroethylene, carbon tetrachloride and chloroform are 3.2, 0.27 and 5.7 µg/l, respectively.) However, the hazard Index (HI_c) for these three chemicals exceeds unity. Rewriting Equation (8-4) in terms of the measured concentration (E_j) and the criterion concentrations (DR_j) shown in Tables 8-5 through 8-8 gives:

$$HI_c = E_1/DR_1 + E_2/DR_2 + E_3/DR_3$$

$$HI_c = \frac{2\ \mu g/l}{3.2\ \mu g/l} + \frac{0.1\ \mu g/l}{0.27\ \mu g/l} + \frac{3\ \mu g/l}{5.7\ \mu g/l}$$

$$HI_c = 0.63 + 0.37 + 0.53$$

$$HI_c = 1.53$$

Thus, in this situation, the need for interim corrective measures and/or a Corrective Measures Study may be assessed.

Contaminant addivity is possible both within a medium and across media. When appropriate, the regulatory agency may use the hazard index approach for multiple contaminants within a given medium to help determine the need for interim corrective measures and/or a Corrective Measures Study. Similarly, contaminant addivity may be applied across media, especially when site-specific factors indicate a likelihood of chronic exposure to constituents from multiple media. Information on the toxicological effects of individual systemic toxicants may be found in the Health and Environmental Effects Documents (HEEDs), and the IRIS data base, referenced earlier.

Worksheet 8-2 (Section 8.10) provides a format that the regulatory agency may use to assess the effects of chemical mixtures based on the hazard index. An example case worksheet is also presented.

8.6 Evaluating Deep Soil and Sediment Contamination

As indicated previously, determining whether deep soil and sediment contamination warrants consideration of interim corrective measures and/or a Corrective Measures Study may involve the application of specific exposure assumptions and consideration of other factors. Guidance regarding these topics is presented below. This guidance may be changed in future editions of this document as a result of ongoing EPA studies.

8.6.1 Deep Soil Contamination

As described in the Soil Section of this Guidance (Section 9), releases of hazardous waste or constituents to soil can be described as surficial (generally affecting the top twelve feet of soil, depending on site-specific conditions) and/or deep (extending below two to twelve feet in depth, depending on site specific conditions). The criteria discussed in Section 8.4 that apply to soil (See Tables 8-6 and 8-7 in Section 8.10) pertain to ingestion of surficial soils. Because ingestion of deep soils may not be a likely exposure scenario, different evaluation methods may be used for deep soils, as described below.

In making the determination of whether interim corrective measures and/or a Corrective Measures Study should be considered for deep contaminated soils, the regulatory agency may assess the potential for the contamination within deep soils to contaminate underlying ground water. If the potential exists for contaminated deep soils to release hazardous constituents to ground water, such that the criteria levels for ground water discussed in Section 8.4 may be exceeded, interim corrective measures and/or a Corrective Measures Study will be considered. This applies not only to situations where ground water has not yet been impacted by deep soil contamination, but also where deep contaminated soils are acting as a continuous source of contamination to already contaminated ground water. In addition, the regulatory agency may apply this evaluation method to surficial soils, particularly in cases where the soil ingestion criteria (Section 8.4) are not exceeded and where the surficial soil may pose a future or continuous threat to ground water.

In order to determine whether contaminated soils pose a future or continuing threat to ground water, leaching tests or other evaluation procedures may be performed on representative samples of contaminated soils following the guidance presented in Section 9.4.4.3. If the concentration of constituents of concern measured in leachate resulting from application of leaching tests or other procedures exceeds the applicable criteria discussed in Section 8.4, interim corrective measures and/or a Corrective Measures Study may be necessary, unless the owner or operator demonstrates (following the guidance presented in Section 9.4.4.3) that attenuation and other mechanisms will reduce these concentrations to acceptable levels prior to entry into the uppermost aquifer.

Case Study No. 17 in Volume IV (Case Study Examples) illustrates the application of leaching tests to determine whether contaminated soil poses a threat to ground water.

8.6.2 Sediment Contamination

As with deep contaminated soils, direct human exposure to contaminated sediments underlying surface waters is unlikely. However, such sediments may pose risks to both the surface water ecosystem and humans due to toxicity and/or bioaccumulation and biomagnification through the food chain. The regulatory agency may therefore assess the potential for contaminated sediments underlying surface water to act as a continuing or future source of contamination to the water column, to aquatic life that may be present in the surface water, and consequently to humans who may ingest the surface water and/or the aquatic life within the surface water.

Section 13, in addressing releases to surface water, recommends that whenever metal species or organic constituents having bioaccumulative potential are known to be present in bottom sediments (or in the water column), that biomonitoring (e.g., aquatic species sampling and analysis) be conducted. If potentially bioaccumulative organic or inorganic contaminants (as discussed in Section 13) are measured in the aquatic species of interest, interim corrective measures and/or a Corrective Measures Study may be necessary.

If other hazardous constituents (e.g., those which are not known to be potentially bioaccumulative) are measured in the sediment that can be subsequently released from the sediment into the surface water column at concentrations above the applicable criteria presented in Section 8.4, interim corrective measures and/or a Corrective Measures Study may also be required by the regulatory agency.

However, the owner or operator may attempt to show that constituents within the sediment have not bioaccumulated or will not bioaccumulate. The owner or operator may also attempt to show, through use of static or flow-through testing (i.e., analysis of water or aquatic species following a period of contact with the contaminated sediment) or through the use of chemical stability/solubility information, that sediment contaminants will not be released to the water column in concentrations that would exceed the applicable criteria discussed in Section 8.4

It should also be noted that EPA is working to establish numerical sediment quality criteria that can be applied on a site-specific basis, depending primarily on the physical/chemical characteristics of the sediment (e.g., sediment organic carbon content). Although these criteria are still in the development/validation process, when developed, they may be applied in the case of sediment contamination to determine whether interim corrective measures and/or a Corrective Measures Study may be necessary.

8.7 Qualitative Assessment and Criteria

Qualitative criteria may also be used to assess the need for interim corrective measures and/or a Corrective Measures Study. Qualitative criteria for interim corrective measures are discussed in Section 8.8. Qualitative criteria for assessing the need for conducting a Corrective Measures Study are discussed below.

The regulatory agency may require that a Corrective Measures Study be performed even though quantitative criteria (See Section 8.4) have not been exceeded. Circumstances under which such actions may be appropriate include the following:

- Presence of sensitive human sub-populations (e.g., schools, nursing homes);

- Presence of sensitive ecosystems or endangered species;

- Data indicating that release concentrations may be increasing over time;
- Information indicating that other contaminant sources may be contributing to overall adverse exposure;
- Information indicating that exposure routes other than those addressed by quantitative criteria (e.g., dermal contact and phytoxicity) are important; and
- Additional exposure as a result of normal use of a contaminated medium (e.g., use of contaminated ground water or surface water for drinking as well as for washing, cooking, showering, watering the lawn, etc.).

The above list of circumstances is not exhaustive. The regulatory agency may identify other factors on a case-specific basis.

8.8 Interim Corrective Measures

The development and implementation of a comprehensive corrective action program can be a time-consuming process. Between the time of the identification of a contaminant release and the implementation and completion of definitive corrective measures, existing conditions or further contaminant migration may endanger human health or the environment. Under such conditions, an evaluation of the need for interim corrective measures may be necessary. Population exposure should be prevented or minimized to the extent necessary and further release migration should also be prevented or minimized.

The process of determining whether interim corrective measures should be taken, and the selection and implementation of such measures, is similiar to removal actions that may be taken under CERCLA (Superfund). In many cases, such action may be relatively simple (e.g., removal of drums from the land surface with proper storage or disposal), while in other cases more extensive action may be necessary.

In evaluating whether interim corrective measures may be necessary, the regulatory agency will review pertinent information about the source and nature of the release or potential threat of release. The regulatory agency will apply scientific judgment in evaluating the potential threat to human health or the environment. The decision to apply interim corrective measures will be made in consideration of the immediacy and magnitude of the potential threat, the nature of appropriate corrective action, and the implications of deferring corrective measures until the RCRA Facility Investigation/Corrective Measures Study is completed. The following factors will be considered in determining the need for interim corrective measures:

- Actual or potential exposure of nearby human populations or animals to hazardous wastes or constituents;
- Actual or potential contamination of drinking water supplies or sensitive ecosystems;
- Presence of hazardous wastes or constituents in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release;
- Presence of high concentrations of hazardous wastes or constituents in soils largely at or near the surface that may migrate readily to receptors, or to which the public may be inadvertently or unknowingly exposed;
- Weather conditions that may cause hazardous wastes or constituents to migrate or be released;
- Threat of fire or explosion; and
- Other situations or factors that may pose actual or imminent threats to human health or the environment.

Exceedance of any of the criteria discussed in Section 8.4 does not necessarily mean that interim corrective measures will be required. Although the regulatory agency should be notified if health and environmental criteria are exceeded, the overall circumstances will be considered by the regulatory agency in determining whether interim corrective measures should be applied. Notwithstanding this process, the owner or operator has a continuing responsibility to identify and respond to emergency situations and to define priority situations that may warrant interim corrective measures. For such situations, the owner or operator should follow the RCRA Facility Contingency Plan as required under 40 CFR Part 264, Subpart D and Part 265, Subpart D.

The regulatory agency will base the decision on the need to apply interim corrective measures on a determination of the type and magnitude of the potential hazard and an evaluation of the likelihood and effects of actual or potential human or environmental exposures. For example, in the hypothetical case depicted in Figure 8-1, initial measurements at the indicated sampling locations identified constituent concentrations in excess of health and environmental criteria. Accordingly, the owner or operator notified the regulatory agency immediately. The circumstances indicated that human population would be exposed to release constituents before definitive corrective measures could be selected and applied. Therefore, immediate steps to address the hazard were required of the owner or operator. Examples of specific interim corrective measures are provided in Table 8-4. For additional information see RCRA Corrective Action Interim Measures (U.S. EPA, 1987).

To determine whether an actual or potential threat to human health or the environment requires interim corrective measures, the regulatory agency will consider such factors as receptor locations, rate of release migration and its extent. Worksheet No. 3 presented in Section 8.10.2 presents a list of questions that the regulatory agency may consider in making a determination.

The decision to apply interim corrective measures may involve estimates of the rate of release migration and an assessment of potential human or environmental receptors. Estimates of the rate of release migration will generally be based on simple calculations, analytical models, or well understood numerical models. For example, the rate of contaminant migration in ground water will likely be based on time of travel (TOT) calculations or other simple methods for estimating rate. Additional information on determining media-specific migration and the characterization of exposed populations is provided in the Superfund Public Health Evaluation Manual (U.S. EPA, 1986) and the Draft Superfund Exposure Assessment Manual (U.S. EPA, 1987).

Table 8-4

EXAMPLES OF INTERIM CORRECTIVE MEASURES

SOILS • Sampling/Analysis/Disposal • Run-off/Run-on Control (Diversion or Collection Devices) • Temporary Cap/Cover	**CONTAINERS** • Overpack/Re-drum • Construct Storage Area/Move to Storage Area • Segregation • Sampling and Analysis • Treatment, Storage and/or Disposal • Temporary Cover
GROUND WATER • Delineation/Verification of Gross Contamination • Sampling and Analysis • Interceptor Trench/Sump/Subsurface Drain • Pump and Treat • In-situ Treatment • Temporary Cap/Cover	**TANKS** • Overflow/Secondary Containment • Leak Detection/Repair/Partial or Complete Removal
SURFACE WATER RELEASE (Point and Non-Point) • Overflow/Underflow Dams • Filter Fences • Run-off/run-on Control (Diversion or Collection Devices) • Regrading/Revegetation • Sample and Analyze Surface Waters and Sediments or Point Source Discharges	**SURFACE IMPOUNDMENTS** • Reduce Head • Remove Free Liquids and or Highly Mobile Wastes • Stabilize/Repair Side Walls, Dikes or Liner(s) • Temporary Cover • Run-off/Run-on Control (Diversion of Collection Devices) • Sample and Analysis to Document the Concentration of Constituents Left in Place When a Surface Impoundment Handling Characteristic Wastes is Clean Closed • Interim Ground-water Measures (See Ground-water Section)
GAS MIGRATION CONTROL • Barriers/Collection/Treatment/Monitoring • Evacuation (Buildings)	**LANDFILL** • Run-off/Run-on Control (Diversion or Collection Devices) • Reduce Head on Liner and/or in Leachate Collection System • Inspect Leachate Collection/Removal System or French Drain • Repair Leachate Collection/Removal System or French Drain • Temporary Cap • Waste Removal (See Soils Section) • Interim Ground-water Measures (See Ground-water Section)

Table 8-4

EXAMPLES OF INTERIM CORRECTIVE MEASURES

PARTICULATE EMISSIONS • Truck Wash (Decontamination Unit) • Re-vegetation • Application of Dust Supressent	**WASTE PILE** • Run-off/Run-on Control (Diversion to Collection Devices) • Temporary Cover • Waste Removal (See Soils Section) • Interim Ground-Water Measures (See Ground-water Section)
OTHER TYPES OF ACTIONS • Fencing to Prevent Direct Contact • Extend Contamination Studies to Off-site Areas if Permission is Obtained as Required Under Section §3004(v) • Alternate Water Supply to Replace Contaminated Drinking Water • Temporary Relocation of Exposed Population • Temporary or Permanent Injunction • Suspend or Revoke Authorization to Operate Under Interim Status	

As discussed above, the determination of the type and magnitude of the potential hazard posed by most contaminant releases will be accomplished as part of the assessment, including the comparison of projected or actual exposure concentrations to the health and environmental criteria, as described in Section 8.4. However, the evaluation of subsurface releases of methane gas may pose a direct explosion hazard as a result of a concentration build-up (e.g., in building structures). Explosions of methane gas can occur at the Lower Explosive Limit (LEL) in the presence of a heat source (e.g., a spark). EPA has promulgated criteria for explosive gases under the RCRA, Subtitle D program in 40 CFR Part 257.3. These criteria state that the concentration of explosive gases generated by the facility shall not exceed: (1) 25 percent of the lower explosive limit (LEL) for the gases in facility structures, and (2) the lower explosive limit for the gases at the property boundary. Where these criteria are being approached or exceeded, interim corrective measures for gas migration will generally be necessary.

8.9 References

U.S. EPA. 1986. Superfund Public Health Evaluation Manual. EPA/540-1-86-060. NTIS PB87-183125. OSWER Directive No. 9285.4-1. Office of Emergency and Remedial Response. Washington, D.C. 20460.

U.S. EPA. September 24, 1986. Guidelines for Carcinogen Risk Assessment. Federal Register 51(185):33992-34003.

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U.S. EPA. 1986. Test Methods for Evaluating Solid Wastes. EPA/SW-846. GPO No. 955-001-00000.1. Office of Solid Waste. Washington, D.C. 24060.

U.S. EPA. 1986. Superfund Exposure Assessment Manual. Draft. Office of Emergency and Remedial Response. Washington, D.C. 20460.

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Emergency and Remedial Response and Office of Waste Programs Enforcement. Washington, D.C. 20460.

U.S. EPA. 1987. Integrated Risk Information System (IRIS) Chemical Files. EPA/600/8-86/032b. Office of Health and Environmental Assessment, Office of Research and Development. Washington, D.C. 20460.

U.S. EPA. 1987. Background Document, Resource Conservation and Recovery Act, Subtitle C--Identification and Listing of Hazardous Waste, Appendix A--Health and Environmental Effects Documents. Office of Solid Waste. Washington, D.C. 20460.

U.S. EPA. 1987. RCRA Corrective Action Interim Measures. Office of Solid Waste. Washington, D.C. 20460.

8.10 Criteria Tables and Worksheets

This section presents both the health and environmental assessment criteria tables and worksheets that the regulatory agency may use in conducting the health and environmental assessment.

8.10.1 Criteria Tables

The following are the health and environmental assessment criteria tables which were discussed in Section 8.4. Table 8-5 presents the Maximum Contaminant Levels (MCLs) promulgated under the Safe Drinking Water Act. Table 8-6 presents health-based criteria for carcinogens (Risk Specific Doses or RSDs). Table 8-7 presents health-based criteria for systemic toxicants (Reference Doses or RfDs). Table 8-8 presents a summary of the Water Quality Criteria developed under the Clean Water Act. Table 8-8 identifies individual constituents as well as groups of constituents (e.g., chlorinated benzenes). Table 8-9 presents a list of all the individual constituents contained in chemical groups identified in Table 8-8.

Table 8-5

MAXIMUM CONTAMINANT LEVELS (MCLs) PROMULGATED UNDER THE SAFE DRINKING WATER ACT*

Chemical	CAS No.	MCL (mg/l)
Arsenic	7440-38-2	0.05
Barium	7440-39-3	1.0
Benzene	71-343-2	0.005
Cadmium	7440-43-9	0.01
Carbon Tetrachloride	56-23-5	0.005
Chromium (hexavalent)	7440-47-3	0.05
2,4-Dichlorophenoxy acetic acid	94-75-7	0.1
1,4-Dichlorobenzene	106-46-7	0.075
1,2-Dichloroethane	107-06-2	0.005
1,1-Dichloroethylene	75-35-4	0.007
Endrin	72-20-8	0.0002
Lindane	58-89-9	0.004
Lead	7439-92-1	0.05
Mercury	7439-97-6	0.002
Methoxychlor	72-43-5	0.1
Selenium	7782-49-2	0.01
Silver	7440-22-4	0.05
Toxaphene	8001-35-2	0.005
1,1,1-Trichloroethane	71-55-6	0.2
Trichloroethylene	79-01-6	0.005
2,4,5-Trichlorophenoxy acetic acid	93-76-5	0.01
Vinyl Chloride	75-01-4	0.002

* These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-6. Health-Based Criteria for Carcinogens[1]

Constituent	CAS No.	Class (A, B, C)[2]	Oral Exposure Route RSD[3]			Inhalation Exposure Route RSD[3]	
			CPF (mg/kg/day)$^{-1}$	Soil (mg/kg)	Water (µg/l)	CPF (mg/kg/day)$^{-1}$	Air (µg/m^3)
Acrylamide[4]	79-06-1	B	3.85E+00	9.09E-02	9.09E-03	3.85E+00	9.09E-04
Acrylonitrile	107-13-1	B	5.4E-01	6.5E-01	6.5E-02	2.4E-01	1.5E-02
Aldrin	309-00-2	B	1.7E+01	2.1E-02	2.1E-03	1.7E+01	2.1E-04
Aniline[4]	62-53-3	C	2.6E-02	1.3E+02	1.3E+01	2.59E-02	1.35E+00
Arsenic[4]	7440-38-2	A	1.58E+01	2.22E-02	2.22E-03	1.51E+01	2.32E-04
Benz(a)anthracene[4]	56-55-3	B	3.12E+00	1.12E-01	1.12E-02	3.12E+00	1.12E-03
Benzene[4]	71-43-2	A	2.87E-02	1.22E+01	1.22E+00	2.87E-02	1.22E-01
Benzidine	92-87-5	A	2.3E+02	1.5E-03	1.5E-04	2.3E+02	1.5E-05
Benzo(a)pyrene[4]	50-32-8	B	1.15E+01	3.04E-02	3.04E-03	1.15E+01	3.04E-04
Beryllium[4]	7440-41-7	B	4.90+00	7.14E-02	7.14E-03	8.40E+00	4.17E-04
Bis(2-chloroethyl) ether	111-44-4	B	1.1E+00	3.2E-01	3.2E-02	1.1E+00	3.2E-03
Bis(chloromethyl) ether (BCME)[4]	542-88-1	A	9.45E+00	3.70E-02	3.70E-03	9.45E+00	3.70E-04
Cadmium	7440-43-9	β	--	--	--	6.1E+00	5.7E-04
Carbon tetrachloride	56-23-5	B	1.3E-01	2.7E+00	2.7E-01	1.3E-01	2.7E-02
Chlordane	57-74-9	B	1.3E+00	2.7E-01	2.7E-02	1.3E+00	2.7E-03
1-Chloro-2, 3-epoxypropane (Epichlorohydrin)	106-89-8	B	9.9E-03	3.5E+01	3.5E+00	4.8E-03	7.3E-01
Chloroform	67-66-3	B	6.1E-03	5.7E+01	5.7E+00	8.1E-02	4.3E-02
Chloromethyl methyl ether[4] (CMME)	107-30-2	A	9.45E+00	3.70E-02	3.70E-03	9.45E+00	3.70E-04
Chromium (hexavalent)	7440-47-3	A	--	--	--	4.1E+01	8.5E-05
DDD	72-54-8	B	2.4E-01	1.5E+00	1.5E-01	--	--
DDE	72-55-9	B	3.4E-01	1.0E+00	1.0E-01	--	--
DDT	50-29-3	B	3.4E-01	1.0E+00	1.0E-01	3.4E-01	1.0E-02
Dibenz(a,h) anthracene[4]	53-70-3	B	4.90E+01	7.14E-03	7.14E-04	4.90E+01	7.14E-05
1,2-Dibromo-3-chloropropane[4] (DBCP)	96-12-8	B	2.21E+01	1.58E-02	1.58E-03	2.21E+01	1.58E-04

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-6. (continued)[1]

Constituent	CAS No.	Class (A, B, C)[2]	Oral Exposure Route RSD[3]			Inhalation Exposure Route RSD[3]	
			CPF $(mg/kg/day)^{-1}$	Soil (mg/kg)	Water (µg/l)	CPF $(mg/kg/day)^{-1}$	Air $(\mu g/m^3)$
1,2-Dibromoethane	106-93-4	B	7.0E+01	5.0E-03	5.0E-04	7.6E-01	4.6E-03
Dibutylnitrosamine	924-16-3	B	5.40E+00	6.48E-02	6.48E-03	5.40E+00	6.48E-04
1,2-Dichloroethane	107-06-2	B	9.1E-02	3.8E+00	3.8E-01	9.1E-02	3.8E-02
1,1 Dichloroethylene	75-35-4	C	6.0E-01	5.8E+00	5.8E-01	1.2E+00	2.9E-02
Dichloromethane (Methylene chloride)	75-09-2	B	7.5E-03	4.7E+01	4.7E+00	1.4E-02	2.5E-01
1,3 Dichloropropene	542-75-6	B	1.8E-01	1.9E+00	1.9E-01	--	--
Dieldrin	60-57-1	B	1.6E+01	2.2E-02	2.2E-03	1.6E+01	2.2E-04
Diethylnitrosamine	55-18-5	B	1.5E+02	2.3E-03	2.3E-04	1.5E+02	2.3E-05
Diethylstilbestrol[4] (DES)	56-53-1	A	4.90E+02	7.14E-04	7.14E-05	4.90E+02	7.14E-06
2,4-Dinitrotoluene	121-14-2	B	3.08E-01	1.14E+00	1.14E-01	--	1E-01
1,4-Dioxane	123-91-1	B	4.90E-03	7.14E+01	7.14E+00	4.90E-03	7.14E-01
1,2-Diphenylhydrazine	122-66-7	B	8.0E-01	4.4E-01	4.4E-02	8.0E-01	4.4E-03
Ethylene oxide[4]	75-21-8	B	3.50E-01	1.00E+00	1.00E-01	3.50E-01	1.00E-02
Heptachlor	76-44-8	B	4.5E+00	7.8E-02	7.8E-03	4.5E+00	7.8E-04
Heptachlor epoxide	1024-57-3	B	9.1E+00	3.8E-02	3.8E-03	9.1E+00	3.8E-04
Hexachlorobenzene[4]	118-74-1	B	1.72E+00	2.03E-01	2.03E-02	1.72E-02	2.03E-01
Hexachlorobutadiene	87-68-3	C	7.8E-02	4.5E+01	4.5E+00	7.8E-02	4.5E-01
Hexachlorodibenzo-p-dioxin	19408-74-3	B	6.2E+03	5.6E-05	5.6E-06	6.2E+03	5.6E-07
Hexachloroethane	67-72-1	C	1.4E-02	2.5E+02	2.5E+01	1.4E-02	2.5E+00
Hydrazine	302-01-2	B	3.0E+00	1.2E-01	1.2E-02	1.02E+01	3.43E-04
Hydrazine sulfate	10034-93-2	B	3.0E+00	1.2E-01	1.2E-02	--	--
Lindane (gamma-Hexachlorocyclohexane)	58-89-9	C	1.3E+00	2.7E+00	2.7E-01	1.3E+00	2.7E-02
3-Methyl-cholanthrene[4]	56-49-5	B	9.45E+00	3.70E-02	3.70E-03	9.45E+00	3.70E-04
4,4-Methylene-bis-(2-chloroaniline)[4]	101-14-4	B	1.65E-01	2.12E+00	2.12E-01	1.65E-01	2.12E-02
Nickel[4]	1440-02-0	A	--	--	--	8.40E-01	4.17E-03
Nickel (refinery dust)	7440-02-0	A	--	--	--	8.4E-01	4.2E-03

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-6. (continued)[1]

Constituent	CAS No.	Class (A, B, C)[2]	Oral Exposure Route RSD[3]			Inhalation Exposure Route RSD[3]	
			CPF (mg/kg/day)$^{-1}$	Soil (mg/kg)	Water (µg/l)	CPF (mg/kg/day)$^{-1}$	Air (µg/m^3)
Nickel subsulfide	12035-72-2	A	--	--	--	1.7E+00	2.1E-03
2-Nitropropane[4]	79-46-9	B	9.45E+00	3.70E-02	3.70E-03	9.45E+00	3.70E-04
N-Nitrosodi-ethanolamine	1116-54-7	B	2.8E+00	1.3E-01	1.3E-02	--	--
N-Nitrosodimethyl-amine (Dimethyl-nitrosamine)	62-75-9	B	5.1E+01	6.9E-03	6.9E-04	5.1E+01	6.9E-05
N-Nitrosodi-N-propylamine	621-64-7	B	7.0E+00	5.0E-02	5.0E-03	--	--
N-Nitroso-N-methylethylamine	10595-95-6	B	2.2E+01	1.6E-02	1.6E-03	--	--
N-Nitroso-N-methyl urea[4]	684-93-5	B	3.01E+02	1.16E-03	1.16E-04	3.01E+02	1.16E-05
N-Nitroso-pyrrolidine	930-55-2	B	2.1E+00	1.7E-01	1.7E-02	2.1E+00	1.7E-03
PCB's	1336-36-2	B	7.7E+00	4.5E-02	4.5E-03	--	--
Pentachloronitro-benzene[4]	82-68-8	C	2.56E-01	1.37E+01	1.37E+00	2.56E-01	1.37E-01
Perchloroethylene (Tetrachloro-ethylene)	127-18-4	C	5.1E-02	6.9E+01	6.9E+00	2.5E-01	1.4E-01
Pronamide (Kerb)[4]	23950-58-5	C	--	--	--	--	2E+00
Reserpine[4]	50-55-5	B	1.05E+01	3.33E-02	3.33E-03	1.05E+01	3.33E-04
1,1,2,2-Tetrachloroethane	79-34-5	C	2.00E-01	1.75E+01	1.75E+00	2.00E-01	1.75E-01
Thiourea[4]	62-56-6	B	1.93E+00	5.18E-01	5.18E-02	1.93E+00	5.18E-03
Toxaphene	8001-35-2	B	1.1E+00	3.2E-01	3.2E-02	1.1E+00	3.2E-03
1,1,2-Trichloroethane	79-00-5	C	5.7E-02	6.1E+01	6.1E+00	5.7E-02	6.1E-01
Trichloroethylene	79-01-6	B	1.1E-02	3.2E+01	3.2E+00	1.3E-02	2.7E-01
2,4,6-Trichlorophenol	88-06-2	B	2.0E-02	1.8E+01	1.8E+00	2.0E-02	1.8E-01

[1] These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

[2] The EPA Carcinogen Classification system is discussed in 51 FR 33992-34003 (Guidelines for Carcinogen Risk Assessment)

[3] See Table 8-2 for the appropriate intake assumptions used to derive these criteria.

[4] Indicates criteria undergoing EPA review.

Table 8-7 Health-Based Criteria for Systemic Toxicants[1]

Constituent	CAS No.	RfD[2] (mg/kg/day)	Soil (mg/kg)	Water (µg/l)
Acetonitrile	75-05-8	6E-03	1E+02	2E+02
Aldicarb	116-06-3	1E-03	2E+01	4E+01
Aldrin	309-00-2	3E-05	5E-01	1E+00
Allyl alcohol	107-18-6	5E-03	9E+01	2E+02
Aluminum phosphide	20859-73-8	4E-04	7E+00	1E+01
Antimony	7440-36-0	4E-04	7E+00	1E+01
Barium	7440-39-3	5E-02	9E+02	2E+03
Barium cyanide	542-62-1	7E-02	1E+03	2E+03
Benzidine	92-87-5	2E-03	3E+01	7E+01
Beryllium	7440-41-7	5E-03	9E+01	2E+02
Bis(2-ethylhexyl) phthalate	117-81-7	2E-02	3E+02	7E+02
Bromoform	75-25-2	2E-02	3E+02	7E+02
Bromomethane	74-83-9	4E-04	7E+00	1E+01
Calcium cyanide	592-01-8	4E-02	7E+02	1E+03
Carbon disulfide	75-15-0	1E-01	2E+03	4E+03
Carbon tetrachloride	56-23-5	7E-04	1E+01	2E+01
Chlordane	57-74-9	5E-05	9E-01	2E+00
Chlorine cyanide	506-77-4	5E-02	9E+02	2E+03
Chlorobenzene	108-90-7	3E-02	5E+02	1E+03
1-Chloro-2,3 epoxypropane (Epichlorohydrin)	106-89-8	2E-03	3E+01	7E+01
Chloroform	67-66-3	1E-02	2E+02	4E+02
Chromium (III)	16065-83-1	1E+00	2E+04	4E+04
Chromium (VI)	7440-47-3	5E-03	9E+01	2E+02
Copper cyanide	544-92-3	7E-02	1E+03	2E+03
Cresols	1319-77-3	5E-02	9E+02	2E+03
Cyanide		2E-02	3E+02	7E+02
Cyanogen	460-19-5	4E-02	7E+02	1E+03
2,4-D	94-75-7	1E-02	2E+02	4E+02
DDT	50-29-3	5E-04	9E+00	2E+01
Di-n-butylphthalate	84-74-2	1E-01	2E+03	4E+03

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-7 (continued)[1]

Constituent	CAS No.	RfD[2] (mg/kg/day)	Soil (mg/kg)	Water (µg/l)
Dichlorodifluoromethane	75-71-8	2E-01	3E+03	7E+03
1,1-Dichloroethylene	75-35-4	9E-03	2E+02	3E+02
Dichloromethane (Methylene chloride)	75-09-2	6E-02	1E+03	2E+03
2,4-Dichlorophenol	120-83-2	3E-03	5E+01	1E+02
1,3-Dichloropropene	26952-23-8	3E-04	5E+00	1E+01
Dieldrin	60-57-1	5E-05	9E-01	2E+00
Diethyl phthalate	84-66-2	8E-01	1E+04	3E+04
Dimethoate	60-51-5	2E-02	3E+02	7E+02
2,4-Dinitrophenol	51-28-5	2E-03	3E+01	7E+01
Dinoseb	88-85-7	1E-03	2E+01	4E+01
Diphenylamine	127-39-4	3E-02	5E+02	1E+03
Disulfoton	298-04-4	4E-05	7E-01	1E+00
Endosulfan	115-29-7	5E-05	9E-01	2E+00
Endothal	145-73-3	2E-02	3E+02	7E+02
Heptachlor	76-44-8	5E-04	9E+00	2E+01
Heptachlor epoxide	1024-57-8	1E-05	2E-01	4E-01
Hexachlorobutadiene	87-68-3	2E-03	3E+01	7E+01
Hexachlorocyclopentadiene	77-47-4	7E-03	1E+02	2E+02
Hexachloroethane	67-72-1	1E-03	2E+01	4E+01
Hydrogen cyanide	74-90-8	2E-02	3E+02	7E+02
Hydrogen sulfide	7783-06-4	3E-03	5E+01	1E+02
Isobutyl alcohol	78-83-1	3E-01	5E+03	1E+04
Lindane (hexachlorocyclohexane)	58-89-9	3E-04	5E+00	1E+01
Maleic hydrazide	108-31-6	5E-01	9E+03	2E+04
Methomyl	16752-77-5	3E-02	5E+02	1E+03
Methyl ethyl ketone	78-93-3	5E-02	9E+02	2E+03

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-7 (continued)[1]

Constituent	CAS No.	RfD[2] (mg/kg/day)	Soil (mg/kg)	Water (µg/l)
Methyl mercury	22967-92-6	3E-04	5E+00	1E+01
Methyl parathion	298-00-0	3E-04	5E+00	1E+01
Nickel	7440-02-0	2E-02	3E+02	7E+02
Nitric oxide	10102-43-9	1E-01	2E+03	4E+03
Nitrobenzene	98-95-3	5E-04	9E+00	2E+01
Nitrogen dioxide	10102-44-0	1E+00	2E+04	4E+04
Octamethylpyrophosphoramide	152-16-9	2E-03	3E+01	7E+01
Osmium tetroxide	20816-12-0	1E-05	2E-01	4E-01
Parathion	56-38-2	3E-04	5E+00	1E+01
Pentachlorobenzene	608-93-5	8E-04	1E+01	3E+01
Pentachloronitrobenzene	82-68-8	3E-03	5E+01	1E+02
Pentachlorophenol	87-86-5	3E-02	5E+02	1E+03
Perchloroethylene (Tetrachloroethylene)	127-18-4	1E-02	2E+02	4E+02
Phenol	108-95-2	4E-02	7E+02	1E+03
Phenyl mercuric acetate	62-38-4	8E-05	1E+00	3E+00
Phosphine	7803-51-2	3E-04	5E+00	1E+01
Potassium cyanide	151-50-8	5E-02	9E+02	2E+03
Potassium silver cyanide	506-61-6	2E-01	3E+03	7E+03
Pronamide (Kerb)	23950-58-5	8E-02	1E+03	3E+03
Pyridine	110-86-1	1E-03	2E+01	4E+01
~~Selenious Acid~~	7782-49-2	3E-03	5E+01	1E+02
Selenourea	630-10-4	5E-03	9E+01	2E+02
Silver	7440-22-4	3E-03	5E+01	1E+02
Silver cyanide	506-64-9	1E-01	2E+03	4E+03
Silvex (2,4,5-TP)	93-72-1	8E-03	1E+02	3E+02
Sodium cyanide	143-33-9	4E-02	7E+02	1E+03
Strychnine	57-24-9	3E-04	5E+00	1E+01
1,2,4,5-Tetrachlorobenzene	95-94-3	3E-04	5E+00	1E+01

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-7 (continued)[1]

Constituent	CAS No.	RfD[2] (mg/kg/day)	Soil (mg/kg)	Water (µg/l)
2,3,4,6-Tetrachlorophenol	58-90-2	3E-02	5E+02	1E+03
Tetraethyl lead	78-00-2	1E-07	2E-03	4E-03
Thallic oxide	1314-32-5	4E-04	7E+00	1E+01
Thallium acetate	563-68-8	5E-04	9E+00	2E+01
Thallium carbonate	6533-73-9	4E-04	7E+00	1E+01
Thallium chloride	7791-12-0	4E-04	7E+00	1E+01
Thallium nitrate	10102-45-1	5E-04	9E+00	2E+01
Thallium selenite	12039-52-0	5E-04	9E+00	2E+01
Thallium sulfate	10031-59-1	3E-04	5E+00	1E+01
Thiram	137-26-8	5E-03	9E+01	2E+02
Toluene	108-88-3	3E-01	5E+03	1E+04
1,2,4-Trichlorobenzene	120-82-1	2E-02	3E+02	7E+02
1,1,1-Trichloroethane	71-55-6	9E-02	2E+03	3E+03
1,1,2-Trichloroethane	79-00-5	2E-01	3E+03	7E+03
Trichloromonofluoromethane	75-69-4	3E-01	5E+03	1E+04
2,4,5-Trichlorophenol	95-95-4	1E-01	2E+03	4E+03
2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	93-76-5	3E-03	5E+01	1E+02
1,2,3-Trichloropropane	96-18-4	6E-03	1E+02	2E+02
Vanadium pentoxide	1314-62-1	2E-02	3E+02	7E+02
Warfarin	81-81-2	3E-04	5E+00	1E+01
Zinc cyanide	557-21-1	5E-02	9E+02	2E+03
Zinc phosphide	1314-84-7	3E-04	5E+00	1E+01

[1] These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

[2] See Table 8-2 for the appropriate intake assumptions used to derive these criteria.

Table 8-8. Water Quality Criteria Summary[1]

Chemical	WATER CONCENTRATIONS IN µg/L FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Acenapthene[11]	1,700[8]	520[8]	970[8]	710[8]			1980FR
Acrolein	68[8]	21[8]	55[8]		320 µg	780µg	1980FR
Acrylonitrile	7,550[8]	2,600[8]			0.058 µg[9]	0.65µg[9]	1980FR
Aldrin	3.0		1.3		0.074ng[9]	0.079ng[9]	1980FR
Alkalinity[11]		20,000					1976RB
Ammonia[2,11]							1985FR
Antimony	9,000[8]	1,600[8]			146µg	45,000 µg	1980FR
Arsenic					2.2ng[9]	17.5ng[9]	1980FR
Arsenic (PENT)	850[8]	48[8]	2,319[8]	13[8]			1985FR
Arsenic (TRI)	360	190	69	36			1985FR
Asbestos[11]					30k f/L[9]		1960FR
Bacteria[3,11]							1966FR
Barium					1mg		1976RB
Benzene	5,300[8]		5,100[8]	700[8]	0.66µg[9]	40µg[9]	1980FR
Benzidine	2,500[8]				0.12ng[9]	0.53ng[9]	1980FR
Beryllium	130[8]	5.3[8]			6.8ng[9]	117ng[9]	1980FR
BHC	100[8]		0.34[8]				1980FR
Cadmium	3.9[7]	1.1[7]	43	9.3	10µg		1985FR
Carbon tetrachloride	35,200[8]		50,000[8]		0.4µg[9]	6.94µg[9]	1980FR
Chlordane	2.4	0.0043	0.09	0.004	0.46ng[9]	0.48ng[9]	1980FR
Chlorindated Benzenes	250[8]	50[8]	160[8]	129[8]	488µg		1980FR
Chlorinated Naphthalenes	1,600[8]		7.5[8]				1980FR
Chlorine[11]	19	11	13	7.5			1985FR
Chloroalkyl Ethers[11]	238,000[8]						1980FR

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-8. (continued)[1]

Chemical	WATER CONCENTRATIONS IN µg/L FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Chloroethyl ether (BIS-2).					0.03µg[9]	1.36µg[9]	1980FR
Chloroform	28,900[8]	1,240[8]			0.19µg[9]	15.7µg[9]	1980FR
Chloroisopropyl ether (BIS-2)[11]					34.7µg	4.36mg	1980FR
Chloromethyl ether (BIS)					0.00000376 ng[9]	0.00184µg[9]	1980FR
Chlorophenol 2[11]	4,380[8]	2,000[8]					1980FR
Chlorophenol 4			29,700[8]				1980FR
Chlorophenoxy Herbicides (2,4,5-TP)					10µg		1980FR
Chlorophenoxy Herbicides (2,4,-D)					100µg		1976FR
Chlorpyrifos[11]	0.083	0.041	0.011	0.0056			1986FR
Chloro-4 methyl-3 phenol	30[8]						1980FR
Chromium (HEX)	16	11	1,100	50	50µg		1985FR
Chromium (TRI)	1,700[7]	210[7]	10,300[8]		170mg	3,433mg	1985FR
Color[4,11]							1976RB
Copper[11]	18[7]	12[7]	2.9	2.9			1985FR
Cyanide	22	5.2	1	1	200µg		1985FR
DDT	1.1	0.001	0.13	0.001	0.024ng[9]	0.024ng[9]	1980FR
DDT Metabolite (DDE)	1,050[8]		14[8]				1980FR
DDT Metabolite (TDE)	0.06[8]		3.8[8]				1980FR
Demeton[11]		0.1		0.1			1976RB
Dibutyl phthalate					35mg	154mg	1980FR
Dichlorobenzenes	1,120[8]	763[8]	1,970[8]		400µg	2.6mg	1980FR
Dichlorobenzidine					0.01µg[9]	0.020µg[9]	1980FR

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-8. (continued)[1]

Chemical	WATER CONCENTRATIONS IN µg/L FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Dichloroethane 1,2	118,000^{8}	20,000^{8}	113,000^{8}		0.94µg^{9}	243µg^{9}	1980FR
Dichloroethylenes	11,600^{8}		224,000^{8}		0.033µg^{9}	1.85µg^{9}	1980FR
Dichlorophenol 2,4	2,020^{8}	365^{8}			3.09mg		1980FR
Dichloropropane	23,000^{8}	5,700^{8}	10,300^{8}	3,040^{8}			1980FR
Dichloropropene	6,060^{8}	244^{8}	790^{8}		87µg	14.1mg	1980FR
Dieldrin	2.5	0.0019	0.71	0019	0.071ng^{9}	0.076ng^{9}	1980FR
Diethyl phthalate					350mg	1.8g	1980FR
Dimethyl phenol 2,4	2,120^{8}						1980FR
Dimethyl phthalate				–	313mg	2.9g	1980FR
Dinitrotoluene 2,4					0.11µg^{9}	9.1µg^{9}	1980FR
Dinitrotoluene					70µg	14.3µg	1980FR
Dinitrotoluene	330^{8}	230^{8}	590^{8}	370^{8}			1980FR
Dinitro-o-Cresol 2,4					13.4µg	765µg	1980FR
Dioxin (2,3,7,8-TCDD)	0.01^{8}	0.00001^{8}			0.000013 ng^{9}	0.000014ng^{9}	1984FR
Diphenylhydrazine					42ng^{9}	0.56µg^{9}	1980FR
Diphenylhydrazine 1,2	270^{8}						1980FR
Di-2-ethyl hexyl phthalate					15mg	50mg	1980FR
Endosulfan	0.22	0.056	0.034	0.0087	74µg	159µg	1980FR
Endrin	0.18	0.0023	0.037	0.0023	1µg		1980FR
Ethylbenzene^{11}	32,000^{8}		430^{8}		1.4mg	3.28mg	1980FR
Fluoranthene	3,980^{8}		40^{8}	16^{8}	42µg	54µg	1980FR
Gasses, Total^{4,11} Dissolved							1976RB
Guthion^{11}		0.01		0.01			1976RB

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-8 (continued)[1]

Chemical	WATER CONCENTRATIONS IN µgL FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Haloethers	360[8]	122[8]					1980FR
Halomethanes	11,000[8]		12,000[8]	8,400[8]	0.19µg[9]	15.7µg[9]	1980FR
Heptachlor	0.52	0.0038	0.053	0.0036	0.28ng[9]	0.29ng[9]	1980FR
Hexachloroethane	960[8]	540[8]	940[8]		1.9µg	8.74µg	1980FR
Hexachlorobenzene					0.72ng[9]	0.74ng[9]	1980FR
Hexachlorobutadiene	90[8]	9.3[8]	32[8]		0.45µg[9]	50µg[9]	1980FR
Hexachlorocyclohexane (Lindane)	2.0	0.08	0.16				1980FR
Hexachlorocyclohexane-Alpha[11]					9.2ng[9]	31ng[9]	1980FR
Hexachlorocyclohexane-Beta[11]					16.3ng[9]	54.7ng[9]	1980FR
Hexachlorocyclohexane-Gamma[11]					18.6ng[9]	62.5ng[9]	1980FR
Hexachlorocyclohexane-Technical[11]					12.3ng[9]	41.4ng[9]	1980FR
Hexachlorocyclopentadine	7[8]	5.2[8]	7[8]		206µg		1980FR
Iron[11]		1,000			0.3mg		1976RB
Isophorone[11]	117,000[8]		12,900[8]		5.2mg	520mg	1980FR
Lead	82[7]	3.2[7]	140	5.6	50µg		1985FR
Malathion[11]		0.1		0.1			1976RB
Manganese[11]					50µg	100µg	1976RB
Mercury	2.4	0.012	2.1	0.025	144ng	146ng	1985FR
Methoxychlor		0.03		0.03	100µg		1976RB
Mirex[11]		0.001		0.001			1976RB
Monochlorobenzene					488µg		1980FR
Naphthalene	2,300[8]	620[8]	2,350[8]				1980FR
Nickel	1,400[7]	160[7]	75	8.3	13.4µg	100µg	1986FR
Nitrates[11]					10mg		1976RB

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-8 (continued)[1]

Chemical	WATER CONCENTRATIONS IN µg/L FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Nitrobenzene	27,000[8]		6,680[8]		19.8mg		1980FR
Nitrophenols	230[8]	150[8]	4,850[8]				1980FR
Nitrosamines	5,650[8]		3,300,000[8]		0.8ng[9]	1240ng[9]	1980FR
Nitrosodibutyl-amine N					6.4ng[9]	587ng[9]	1980FR
Nitrosodiethyl-amine N					0.8ng[9]	1,240ng[9]	1980FR
Nitrosodimethyl-amine N					1.4ng[9]	16,000ng[9]	1980FR
Nitrosodiphenyl-amine N					4,900ng[9]	16,100ng[9]	1980FR
Nitrosopyrrolidine N					16ng[9]	91,900ng[9]	1980FR
Oil and Grease[4,11]							1976RB
Oxygen Dissolved[5,11]							1986FR
Parathion	0.065	0.013					1986FR
PCB's	2.0	0.014	10	0.03	0.079ng[9]	0.079ng[9]	1980FR
Pentachlorinated Ethanes	7,240[8]	1,100[8]	390[8]	281[8]			1980FR
Pentachloro-benzene					74g	85µg	1980FR
Pentachlorophenol	20[10]	13[10]	13	7.9[8]	1.01mg		1966FR
pH[11]		6.5-9		6.5-8.5			1976RB
Phenol	10,200[8]	2,560[8]	5,800[8]		3.5mg		1980FR
Phosphorus Elemental[11]				0.1			1976RB
Phthlate Esters	940[8]	3[8]	2,944[8]	3.4[8]			1980FR
Polynuclear Aromatic Hydrocarbons			300[8]		2.8ng[9]	31.1ng[9]	1980FR
Selenium	260	35	410	54	10µg		1980FR
Silver	4.1[7]	0.12	2.3		50µg		1980FR

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Table 8-8. (continued)[1]

Chemical	WATER CONCENTRATIONS IN µg/L FOR AQUATIC LIFE				WATER CONCENTRATIONS IN UNITS PER LITER FOR HUMAN EXPOSURE		Date Reference
	Fresh Acute Criteria	Fresh Chronic Criteria	Marine Acute Criteria	Marine Chronic Criteria	Water and Fish Ingestion	Fish Consumption Only	
Solids Dissolved and Salinity[11]					250mg		1976RB
Solids Suspended and Turbidity[4,11]							1976RB
Sulfide-Hydrogen Sulfide		2		2			1976RB
Temperature[6,11]							1976RB
Tetrachlorinated Ethanes	9,320[8]						1980FR
Tetrachloro-benzene 1,2,4,5					38µg	48µg	1980FR
Tetrachloroethane 1,1,2,2		2,400[8]	9,020[8]		0.17µg[9]	10.7µg[9]	1980FR
Tetrachloroethanes	9,320[8]						1980FR
Tetrachloro-ethylene	5,280[8]	840[8]	10,200[8]	450[8]	0.8µg[9]	8.85µg[9]	1980FR
Tetrachlorophenol 2,3,5,6				440[8]			1980FR
Thallium	1,400[8]	40[8]	2,130[8]		13µg	48µg	1980FR
Toluene	17,500[8]		6,300[8]	5,000[8]	14.3mg	424mg	1980FR
Toxaphene	0.73	0.0002	0.21	0.0002	0.71ng[9]	0.73ng[9]	1986FR
Trichlorinated Ethanes	18,000[8]						1980FR
Trichloroethane 1,1,1			31,200[8]		18.4mg	1.03g	1980FR
Trichloroethane 1,1,2		9,400[8]			0.6µg[9]	41.8µg[9]	1980FR
Trichloroethylene	45,000[8]	21,900[8]	2,000[8]		2.7µg[9]	80.7µg[9]	1980FR
Trichlorophenol 2,4,5					2,600µg		1980FR
Trichlorophenol 2,4,6		970[8]			1.2µg[9]	3.6µg[9]	1980FR
Vinyl Chloride					2µg[9]	525µg[9]	1980FR
Zinc[11]	120[7]	110[7]	95	86			1987FR

Note: These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

Footnotes for Table 8-8

1 This table is for general information purposes only; see criteria documents or detailed summaries in Quality Criteria for Water 1986 for more information. These criteria are subject to change and will be confirmed by the regulatory agency prior to use.

2 Criteria are pH and temperature dependent - See Document (1)

3 For primary recreation and shellfish uses - See Document (1)

4 Narrative statement - See Document (1)

5 Warmwater and coldwater criteria matrix - See Document (1)

6 Species dependent criteria - See Document (1)

7 Hardness Dependent Criteria (100 mg/l used)

8 Insufficient data to develop criteria. Value presented is lowest observed effect level.

9 Human health criteria for carcinogens reported for three risk levels. Value presented in this table is the 10^{-6} risk level.

10 pH dependent criteria - 7.8 pH used.

11 Indicates chemical or parameter not on Appendix VIII. The regulatory agency will exercise discretion prior to requiring such chemicals or parameters to be monitored during the RFI.

General -
g = grams
mg = milligrams
µg = micrograms
ng = nanograms
f = fibers
FR = federal register
RB = Quality Criteria for Water, 1976 (Redbook)

Table 8-9. Individual Listing of Constituents Contained Within Chemical Groups Identified in Table 8-8

Chemical Group	Individual Constituents
Chlorinated Benzenes	Chlorobenzene 1,2,4-Trichlorobenzene Hexachlorobenzene
Chlorinated Ethanes	1,2-Dichloroethane 1,1,1-Trichloroethane Hexachloroethane 1,1-Dichloroethane 1,1,2-Trichloroethane Chloroethane
Chloroalkyl Ethers	Bis(chloromethyl) ether Bis(2-chloroethyl ether 2-Chloroethyl vinyl ether (mixed)
Chlorinated Naphthalene	2-Chloronaphthalene
Chlorinated Phenols	2,4,5-Trichlorophenol Parachlorometa cresol
Dichlorobenzenes	1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene
Dichlorobenzidine	3,3'-Dichlorobenzidine
Dichloroethylenes	1,1-Dichloroethylene 1,2-Trans-dichloroethylene
Dichloropropane and Dichloropropene	1,2-Dichloropropane 1,2-Dichloropropylene (1,3-dichloropropene)
Dinitrotoluene	2,4-Dinitrotoluene 2,5-Dinitrotoluene
Haloethers	4-Chlorophenyl phenyl ether 4-Bromophenyl phenyl ether Bis (2-chloroisopropyl) ether Bis (2-chloroethoxy) methane
Halomethanes	Methylene chloride (dichloromethane) Methyl chloride (chloromethane) Methyl bromide (bromomethane) Bromoform (tribromomethane) Dichlorobromomethane Trichlorofluoromethane Dichlorodifluoromethane Chlorodibromomethane

Table 8-9. (Continued)

Chemical Group	Individual Constituents
Nitrophenols	2-Nitrophenol 4-Nitrophenol 2,4-Dinitrophenol 4,6-Dinitro-o-cresol
Nitrosamines	N-Nitrosodimethylamine N-Nitrosodiphenylamine N-Nitrosodi-n-propylamine
Phthalate Esters	Bis (2-ethylhexyl) phthalate Butyl benzyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Diethyl phthalate Dimethyl phthalate
Polynuclear Aromatic Hydrocarbons	Benzo(a) anthracene (1,2-benzanthracene) Benzo(a) pyrene 3,4-Benzofluoranthene Benzo(k) fluoranthene (11,12-benzofluoranthene) Chrysene Acenaphthylene Anthracene Benzo(ghi)Perylene (1,12-benzoperylene) Fluorene Phenanthrene Dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene) Indeno (1,2,3-cd)pyrene Pyrene
Endosulfan and Metabolites	a-Endosulfan-Alpha p-Endosulfan-Beta Endosulfan sulfate
Endrin and Metabolites	Endrin
Heptachlor and Metabolites	Heptachlor Heptachlor epoxide
Polychlorinated Biphenyls	PCB-1242 (Arochlor 1242) PCB-1254 (Arochlor 1254) PCB-1221 (Arochlor 1221) PCB-1232 (Arochlor 1232) PCB-1248 (Arochlor 1248) PCB-1260 (Arochlor 1260) PCB-1016 (Arochlor 1016)

8.10.2 Worksheets

Worksheets 8-1 and 8-2 may be used by the regulatory agency in comparing constituent concentrations in the release to health and environmental criteria. Example filled in worksheets are also shown. These worksheets address the following:

- 8-1: Comparison of individual contaminant concentrations with criteria
- 8-2: Use of hazard indices for exposure to chemical mixtures.

A questionnaire that may be used in determining if interim corrective measures are necessary is provided in Worksheets 8-3. Questions are posed to help focus the determination. These questions will be addressed to the extent possible based on available information. The regulatory agency will not necessarily need answers for all questions in order to make a decision as to whether interim corrective measures are necessary. If release concentration information is available, Worksheets 8-1 and 8-2 may also be filled out.

WORKSHEET 8-1

COMPARISON OF INDIVIDUAL CONSTITUENT CONCENTRATIONS WITH HEALTH CRITERIA

Facility Name ____________
Releasing Unit ____________
Contaminated Media ____________
Sample Location ____________
Sample Number(s) ____________
Date ____________
Analyst ____________

Exposure Medium	Constituent Released	Release Concentration	Table No. and Criterion Type Used	Criterion Value	Release Concentrations Exceed Criterion?
WATER					
SOIL					
AIR					

INSTRUCTIONS

1. List chemicals with human-health and environmental criteria for the appropriate exposure medium.
2. List chemical concentration for the appropriate exposure medium.
3. List type of human-health and environmental criteria used and applicable table number.
4. List appropriate criteria values.
5. Compare chemical concentration and criteria values and identify whether release concentration exceeds criteria.

EXAMPLE WORKSHEET 8-1

COMPARISON OF INDIVIDUAL CONSTITUENT CONCENTRATIONS WITH HEALTH CRITERIA

Site Name Site X
Releasing Unit Impoundment 2
Contaminated Media Ground Water/Air/Soil
Sample Location MW 2/X-7 (see Map)
Sample Number(s) MW2-1/X-7-1
Date 9/4/86
Analyst JDP

Exposure Medium	Constituent Released	Release Concentration	Table No. and Criterion Type Used	Criterion Value	Release Concentrations Exceed Criterion?
WATER	Trichloroethylene	2 μg/l	Carcinogen Table 8-6	3.2 μg/l	No
	Carbon tetrachloride	0.1 μg/l	Carcinogen Table 8-6	0.27 μg/l	No
	Chloroform	3 μg/l	Carcinogen Table 8-6	5.7 μg/l	No
SOIL	Chlorobenzene	10 mg/kg	Systemic Tox. Table 8-7	500 mg/kg	No
	Pentachlorobenzene	7 mg/kg	Systemic Tox. Table 8-7	10 mg/kg	No
AIR	Trichloroethylene	0.1 μg/m^3	Carcinogen Table 8-6	0.27 μg/m^3	No

INSTRUCTIONS

1. List chemicals with human-health and environmental criteria for the appropriate exposure medium.
2. List chemical concentration for the appropriate exposure medium.
3. List type of human-health and environmental criteria used and applicable table number.
4. List appropriate criteria values.
5. Compare chemical concentration and criteria values and identify whether release concentration exceeds criteria.

WORKSHEET 8-2

USE OF HAZARD INDICES FOR EXPOSURE TO CHEMICAL MIXTURES

Facility Name ____________
Releasing Unit ____________
Contaminated Media ____________
Sample Location ____________
Sample Number(s) ____________
Date ____________
Analyst ____________

Exposure Medium	Constituent Released	Ratio of Release Concentration to Criterion Value	HAZARD INDICES	
			Medium Total	Value Exceeds Unity?
WATER				
SOIL				
AIR				

INSTRUCTIONS

1. List chemicals in each environmental medium, as shown in Worksheet 8-1.
2. Compare chemical concentrations and appropriate health criteria values, as shown in Worksheet 8-1. Determine ratio of release concentration to the criteria values.
3. Determine a hazard index for the chemicals in each medium by summing the ratios calculated by comparing chemical concentrations and health criteria.
4. Determine if the hazard index for the chemical mixture found in each individual exposure medium exceeds unity.

EXAMPLE WORKSHEET 8-2

USE OF HAZARD INDICES FOR EXPOSURE TO CHEMICAL MIXTURES

Site Name Site X

Releasing Unit Impoundment 2

Contaminated Media Ground Water/Air/Soil

Sample Location MW 2/X-7 (see Map)

Sample Number(s) MW2-1/X-7-1

Date 9/4/86

Analyst JDP

Exposure Medium	Constituent Released	Ratio of Release Concentration to Criterion Value	HAZARD INDICES	
			Medium Total	Value Exceeds Unity?
WATER	Trichloroethylene	0.63		
	Carbon tetrachloride	0.37		
	Chloroform	0.53		
			1.53	Yes
SOIL	Chlorobenzene	0.02		
	Pentachlorobenzene	0.7		
			0.72	No
AIR	Trichloroethylene	0.37	0.37	No

INSTRUCTIONS

1. List chemicals in each environmental medium, as shown in Worksheet 8-1.
2. Compare chemical concentrations and appropriate health criteria values, as shown in Worksheet 8-1. Determine ratio of release concentration to the criteria values.
3. Determine a hazard index for the chemicals in each medium by summing the ratios calculated by comparing chemical concentrations and health criteria.
4. Determine if the hazard index for the chemical mixture found in each individual exposure medium exceeds unity.

WORKSHEET 8-3

QUESTIONS TO BE CONSIDERED IN DETERMINING IF INTERIM CORRECTIVE MEASURES MAY BE NECESSARY

In considering the actual or potential threat to human health or the environment posed by a contaminant release, the regulatory agency will consider factors such as type and extent of the release and site demographics. The following questions may be used in evaluating these factors. If sufficient information is available, the worksheets presented on the previous pages may also be used in evaluating the need for interim corrective measures. For further details, see RCRA Corrective Action Interim Measures (U.S. EPA, 1987).

A. Release Characterization

1. What is the source(s) (e.g., nature, number of drums, area, depth, amount, location(s))?

2. Regarding hazardous wastes or constituents at the source(s):

   a. Which hazardous wastes (listed, characteristic) and hazardous constituents are present?

   b. What are their concentrations?

   c. What is the background level of each hazardous waste or constituent?

3. What are the known pathways through which the contamination is migrating or may migrate and the extent of contamination?

   a. Through which media is the release spreading or likely to spread? Direction? Rate?

   b. How far has the release migrated? At what concentrations?

        c. How mobile is the constituent?

        d. What are the estimated quantities and/or volumes released?

    4. What is the projected fate and transport?

B. Potential Human Exposure and Effects

    1. What is or will be the exposure pathway(s) (e.g., air, fire/explosion, ground water, surface water, direct contact, ingestion)?

    2. What are the location and demographics of populations and environmental resources (potentially) at risk from exposure (e.g., residential areas, schools, drinking water supplies, sole source aquifers near vital ecology or protected natural resources)?

    3. What are the potential effects of human exposure (short- and long-term effects)?

    4. Has human exposure actually occurred? Or when may human exposure occur?

        a. What is the exposure route(s) (e.g., inhalation, ingestion, skin contact)?

        b. Are there any reports of illness, injury, or death?

        c. How many people will be affected?

        d. What are the characteristics of the exposed populations(s) (e.g., presence of sensitive populations such as infants or nursing home residents)?

    5. If response is delayed, how will the situation change (e.g., what will be the implications to human health)?

C. Potential Environmental Exposure and Effects

1. What media have been and may be contaminated (e.g., ground water, air, surface water?
2. What are the likely short-term and long-term threats and effects on the environment of the released waste or constituents?
3. What natural resource and environmental effects have occurred or are possible (terrestrial, aquatic organisms, aquifers whether or not used for drinking water)?
4. What are the known or projected ecological effects?
5. When is this threat/effect likely to materialize (days, weeks, months)?
6. What are the projected long term effects?
7. If response is delayed, how will the situation change?

APPENDIX A

AERIAL PHOTOGRAPHY, MAPPING, AND SURVEYING

APPENDIX A

AERIAL PHOTOGRAPHY, MAPPING, AND SURVEYING

Aerial photographs, maps, and surveys can assist in verifying and characterizing contaminant releases and are particularly helpful sources of information that can be used during the development of a monitoring plan. They can also be used, when viewed in historical sense (e.g., over the same location, but at different points in time), to locate old solid waste management units, stream beds, and other facility features. Stereo viewing (using a stereoscope) can further enhance the interpretation of photographs and maps since vertical as well as horizontal spatial relationships can be observed. This Appendix discusses the potential applications of aerial photography, mapping, and surveying in the RFI process.

Case Study Numbers 2, 20, 23 and 24 in Volume IV (Case Study Examples) illustrate the use of several of the techniques presented in this Appendix.

AERIAL PHOTOGRAPHY

Introduction

Aerial photography may be used to gather release verification and characterization information during the RFI. Although detailed aerial photographic analysis usually requires a qualified photo-interpreter, the site information that it can readily provide may warrant its use. Aerial photography can provide valuable information on the environmental setting as well as indications of the nature and extent of contaminant releases. However, when using aerial photographic techniques, important release information should be verified through field observations.

Information Obtained From Aerial Photographs

The basic recognition elements commonly utilized in photographic interpretation are shape, texture, pattern, size, shadow, tone and/or color. Natural color, false color or color infrared, and black and white film are routinely used in aerial photographic applications. Color imagery may be more readily interpreted than black and white film, by providing enhanced differentiation of subtle evidence of such items as surface leachate (e.g., seeps) and surface water quality. Color infrared film offers an added element of information with its near infrared sensitivity by enabling assessment of vegetation type, damage, or stress, and providing a wide range for detection of moisture conditions in soils.

Subsurface characteristics can be inferred by surface information in the photographs. For example, vegetative stress may indicate leachate and gas migration where the water table is shallow or in discharge areas. Infrared may be able to detect vegetative stress not noticeable during a field inspection. Geologic features (variation in the distribution of geologic units, bedrock fractures, fault zones, etc.) that can affect ground-water flow pathways can also be identified from aerial photographs. Fractures at shallow depths in consolidated rocks can serve as pathways for contaminated ground water and for rapid infiltration of surface runoff. Contamination of surface water bodies can be detected by discoloration or shading in aerial photography. Land surface elevation determinations and contour maps can be compiled, and ground-water flow direction in shallow systems can be estimated using this information. The time of year is also an important consideration when interpreting geologic and hydrologic features. For example, the presence of heavy vegetation during the summer months may obscure certain geologic and hydrologic features. As another example, drainage patterns and seasonal high water tables are more readily observed after or during winter snowmelt.

Other information available from aerial photographs includes: Natural topography, drainage and erosional features, vegetative cover and damage, indications of leachate, damaged unit containment structures, etc. Observable patterns, colors, and relief can make it possible to distinguish differences in geology, soils, soil moisture, vegetation, and land use. Aerial photography can also indicate important hydrologic features. Springs and marshy areas represent ground-water discharge areas. In cases of releases to ground water, aerial photographs can indicate the existence of likely contaminant migration pathways (e.g., recharge areas, sink holes, karst terrains, subsurface flow patterns, fissures, and joints). For releases to surface water, aerial photographs can indicate the location of potential contaminant receiving bodies (e.g., ponds and streams) and site runoff channels. Aerial photography can also be used to obtain input information for designing monitoring plans (e.g., defining boundary conditions such as ponds, streams, springs, paved areas, large buildings, irrigation canals).

Major benefits in using aerial photography as a supplement to other investigative methods include:

- Obtaining information on relatively large areas, including surrounding land use and environmental features;
- Indicating effects of contamination; and
- Providing indirect indications of subsurface conditions.

The following limitations should be considered when using aerial photography:

- It does not provide direct information on subsurface characteristics;
- There may be variations in photo quality with age, season of flight, film type, photo scale, cloud cover, etc.; and
- Information obtained from photographs should not be used alone in evaluating surface/subsurface conditions. They should always be verified through field observations.

Use of Existing Aerial Photographs (Historical Analysis)

Existing aerial photographs may be available that show the site prior to the existence of some or all hazardous waste management activities. Individual photographs provide an opportunity to identify specific features and activities at a single point in time. By identifying conditions at a site at several points in time (i.e., historical analysis), the sequence of events leading to the current conditions can be better understood. This process may identify changes in surface drainage conditions through time, locations of landfills, waste treatment ponds/lagoons and their subsequent burial and abandonment, the burial of waste drums, number of drums, estimated depth and horizontal extent of burial pits, sources of spillage, and discharge of liquid wastes, etc. Historical photographic analysis can be used to make maps that reflect conditions that previously existed at a facility if enough control points are provided (e.g., road intersections, power lines, buildings, railroad tracks). This information may be very useful in determining appropriate monitoring locations. Analysis problems that should be considered when using historical photos include variations in placement of the site within a given frame of photography and variations in scale.

Sources

Town or county offices may have aerial photographs on file. Also, most of the United States has been photographed in recent years for various Federal agencies. A map entitled "Status of Aerial Photography in the United States" has been compiled that lists all areas (by county) that have been photographed by or for the Agricultural Stabilization and Conservation Service, the Soil Conservation Service, Forest Service, U.S. Geological Survey, Army Corps of Engineers, Air Force, and commercial firms. These maps are available from:

Map Information Office
U.S. Department of the Interior
Geologic Survey
507 National Center
Reston, VA 22092
(703) 860-6045

The names and addresses of agencies holding negatives for photographs are printed on the back of the map.

The U.S. EPA may also have taken aerial photos of certain facilities. The owner or operator may inquire at specific federal and state regulatory offices for access to any photos that may have been taken. Other sources of aerial photographs are listed below.

Federal government--The following two U.S. Geological Survey locations can provide indices of all published maps and include order blanks, prices, and detailed ordering instructions. They may also provide a list of addresses of local map reference libraries, local map dealers, and Federal map distribution centers.

Eastern Distribution Branch
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202

Western Distribution Branch
U.S. Geological Survey
Box 25286 Denver Federal Center
Denver, CO 80225

Other Federal Agencies Include:

Aerial Photography Field Office
ASCS-U.S. Department of Agriculture (USDA)
P.O. Box 30010
Salt Lake City, Utah 84130
(801) 524-5856

(Has all Agricultural Stabilization and Conservation Service photos, Forest Service photos, etc.)

EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57198
(605) 594-6511 (ext. 151)

(Landsat and U-2 photos, black and white at 1:80,000 scale. Computer listings of all available photos can be accessed)

Soil Conservation Service
USDA-SCS
P.O. Box 6567
Fort Worth, TX 76117
(817) 334-5292

(Supplies mostly low altitude, 1:20,000 scale, photos)

National Archives
841 South Pickett Street
Alexandria, VA 22304
(703) 756-6700

(For historical photos)

All of the above agencies will require some information identifying the site location to locate relevant photos. This information may be in the form of a town engineer's map; Department of Transportation map; description of the township, range, section; a hand-drawn map of the site in relation to another town; precise longitude and latitude coordinates of the site area; or a copy of the portion of a U.S. Geological Survey quadrangle that shows the site.

For facilities near the United States-Canada border, the following agency may provide aerial photographs:

The National Air Photo Library
Surveys and Mapping Branch
Department of Energy, Mines and Resources
615 Booth Street
Ottawa, Ontario K1A OE9

State government--State agencies may also have aerial photographs on file. These include:

- Pollution control agencies;
- Health departments;
- Water resources departments;
- Forestry or Agricultural departments;
- Highway departments; and
- Geological survey departments.

Private companies--Photographs required for the site of concern may be held by private aerial survey companies and can often be ordered directly from these sources. Local telephone listings and Photogrammetric Engineering, the Journal of the American Society of Photogrammetry, can provide sources of information.

Aerial photographic surveys--If existing photographs are not available or do not provide enough information, the owner or operator may arrange for an aerial photographic survey to be conducted. When deciding whether an aerial survey is appropriate, the owner or operator should consider whether the information needs can be filled with data obtained from an aerial survey (or from another source or investigative technique) and the size of the site (for a small site, a ground survey may be more economical). This survey should be conducted by professionals who will plan, schedule, and perform the flight, collect data with appropriate scale and/or film requirements, analyze results, and compile maps, if necessary.

Conducting New Aerial Photographic Surveys--A local telephone listing, the Journal of the American Society of Photogrammetry, or the government agencies listed in this section may provide names of companies or organizations that conduct aerial photographic surveys. When requesting that an aerial photographic survey be conducted, the owner or operator should supply the site location (e.g., marked on a topographic map). Property boundaries and waste management areas should be outlined. If photographic interpretation is also requested, a brief site description, type and number of solid waste management units, and types of wastes handled would also be helpful.

MAPPING

To assist in adequately characterizing a release, various types of maps may be useful. Maps can be used to show geology, hydrology, topography, climate, land use, and vegetative characteristics. Maps can be generated through compilation of existing maps, aerial photographs, or through ground surveys. This section discusses the usefulness of mapping in verifying and characterizing the nature and extent of a release. In general, displaying information from all types of maps can be presented on the facility's existing topographic map as discussed below.

Topographic Maps

The owner or operator should use, to the extent possible, the topographic map and associated information that meets the requirements of 40 CFR Part 270 14(b)(19) of EPA's Hazardous Waste Permit Program which states:

> "A topographic map showing a distance of 1000 feet around the facility at a scale of 2.5 centimeters (1 inch) equal to not more than 61.0 meters (200 feet). Contours must be shown on the map. The contour interval must be sufficient to clearly show the pattern of surface water flow in the vicinity of and from each operational unit of the facility. For example, contours with an interval of 1.5 meters (5 feet), if relief is greater than 6.1 meters (20 feet), or an interval of 0.6 meters (2 feet), if relief is less than 6.1 meters (20 feet). Owners and operators of HWM facilities located in mountainous areas should use large contour intervals to adequately show topographic profiles of facilities. The map shall clearly show the following:
>
> (i) Map scale and date.
> (ii) 100-year floodplain area.
> (iii) Surface waters including intermittent streams.
> (iv) Surrounding land uses (residential, commercial, agricultural, recreational).
> (v) A wind rose (i.e., prevailing wind-speed and direction).
> (vi) Orientation of the map (north arrow).

(vii) Legal boundaries of the HWM facility site.
(viii) Access control (fences, gates).
(ix) Injection and withdrawal wells both onsite and offsite.
(x) Buildings; treatment; storage, or disposal operations; or other structures (recreation areas, runoff control systems, access and internal roads, storm, sanitary, and process sewerage systems, loading and unloading areas, fire control facilities, etc.).
(xi) Barriers for drainage or flood control.
(xii) Location of operational units within the HWM facility site, where hazardous waste is (or will be) treated, stored, or disposed (include equipment cleanup areas)."

Additional information that should be noted on the topographic map is specified in the requirements of 40 CFR Part 270.14(c)(3), which states:

> "On the topographic map required under paragraph (b)(19) of this section, a delineation of the waste management area, the property boundary, the proposed "point of compliance" as defined under §264.95, the proposed location of ground water monitoring wells as required under §264.97, and, to the extent possible, the information required in paragraph (c)(2) of this section.", that being . . . "(2) Identification of the uppermost aquifer and aquifers hydraulically interconnected beneath the facility property, including ground water flow direction and rate, and the basis for such identification (i.e., the information obtained from hydrogeologic investigations of the facility area)."

The use of topographic maps will enable the owner or operator to identify and display many features useful in characterizing a release, such as potential surface water receiving bodies, runoff pathways, and engineered structures.

Sources

Topographic maps of the facility area may be available or obtained from:

- U.S.G.S. (generally with 10-foot contour intervals);
- Local town offices (e.g., Building Department, Board of Assessors);
- Onsite surveying to obtain site specific elevation information; and
- Use of an aerial photographic consultant to fly the site and surrounding area and develop a map.

A site-specific topographic map may be constructed by measuring and plotting land elevations by a stadia survey. This method of surveying determines distances and elevations by means of a telescopic instrument having two horizontal lines through which the marks on a graduated rod are observed. A local telephone directory will usually list companies providing this service.

Existing topographic maps may also be obtained from:

Eastern Distribution Branch
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202
(East of the Mississippi River)

Western Distribution Branch
U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
(West of the Mississippi River)

Before requesting a map, the proper quadrangle must be determined. Maps are indexed by geographic location--longitude and latitude. The quadrangle size is given in minutes or degrees. 7.5 minute quadrangles provide the best resolution.

Other sources of topographic information include:

- Local colleges or universities that may have index map sets;
- Local town officials (town engineers, planners, etc.) who know which quadrangles cover their area;
- Nearby institutions or firms that deal with land holdings are likely to have USGS quadrangles for that area; and
- Local USGS offices, map distributors and other suppliers.

Although for the most part the above identified sources will not supply topographic maps which satisfy the requirements of 40 CFR Part 270, they may still be useful for pointing out old solid waste mangement units and other facility features which may be useful in planning the RFI.

Land Use Maps

Land uses, including residential, commercial, industrial, agricultural, and recreational, should also be shown on the site topographic map. This information is useful for assessing the need for interim corrective measures, and in evaluating potential exposure points and the need for a Corrective Measures Study when air is the medium of contamination.

Sources

Information may be obtained by contacting local officials, conducting first-hand observations, and using a USGS quadrangle. USGS maps indicate structures, including dwellings, places of employment, schools, churches, cemeteries, barns, warehouses, golf courses, and railroad tracks. Various types of boundary lines delineate city limits, national and state reservations, small parks, land grants, etc. Other land use information may be obtained by contacting local planning boards, regional planning commissions, and State agencies. Also, the USGS has special land use maps available for some areas. Inquiries regarding the availability of such maps may be directed to:

Geography Program
Land Information and Analysis Office
USGS-MS 710
Reston, VA 22092
(703) 860-6045

Climatological Maps

Relevant climatological data should be identified. For example, a wind rose graphically displays wind speed and direction. Such information may be critical in the characterization of an air release. Other climatological and meteorological information (e.g., precipitation and temperature) are often important in characterizing releases to the various environmental media. Because many of these types of meteorological and climatological information may not be effectively displayed on the (40 CFR Part 270) topographic map, they should be identified in a separate map or other document.

Sources

National Climatic Center
Department of Commerce
Federal Building
Ashville, NC 28801
(704) 258-2850

The National Climatic Center may also refer the owner or operator to a data collection office in the vicinity of the area of concern. In addition, local libraries and other sources may provide local climatological data for various period storms (e.g., the 100-year storm), and other information.

Floodplain Maps

The 100-year floodplain area, if applicable, should also be included on the facility's topographic map. Special flooding factors (e.g., wave action) or special flood control features included in the design, construction, operation or maintenance of a facility should also be noted. The topographic map submitted should include the boundaries of the site property in relation to floodplain areas.

Sources

The National Flood Insurance Program (NFIP) has prepared Flood Hazard Boundary Maps for flood-prone areas. These maps delineate the boundaries of the 100-year floodplain. Such maps are often included as part of the Flood Insurance Study for a particular political jurisdiction along a waterway. The U.S. Federal Emergency Management Administration (FEMA) located in Washington, D.C. ((202) 246-2500) publishes such studies. Hydraulic analyses used to determine flood level, community description, and principal flood problems and flood protective measures (provided in the flood insurance studies) should also be included. The USGS, U.S. Army Corps of Engineers, U.S. Soil Conversation Service and the Office of Coastal Zone Management may be contacted for further floodplain information.

Additional Information

Other information that should be shown on the topographic map includes:

- Access control (fences, gates, etc.);
- Buildings, treatment, storage, disposal operation areas and other structures nearby or onsite;
- Buried pipeline, sewers and electrical conduits;
- Barriers for drainage or flood control;
- Areas of past spills;
- Location of all existing (active and inactive) solid waste management units;
- Location of nature of industrial and product process and storage units; and
- Facility design features such as run-on/runoff control systems and wind dispersal control systems.

Sources

This information can be obtained from aerial photographs, field observations, operating records, construction and inspection records, etc. The owner or operator may need to locate additional site-specific information. This information may be available on existing maps, such as:

Geomorphology	-	surficial geology maps historical aerial photographs topographic maps
Eolian Erosion and Deposition	-	county soil maps (historical) aerial photographic interpretation topographic maps
Fluvial Erosion and Deposition	-	floodplain maps county soil maps (historical) aerial photographic interpretation topographic maps

Drainage Patterns -

- topographic maps
- county soil maps
- hydrologic maps
- aerial photgraphic interpretation

Geologic Features -

- bedrock geology maps
- county soil maps
- topographic maps

Land Use -

- zoning maps
- current aerial photos
- local conservation commission maps
- county soil
- recent topographic maps

Hydrologic Features -

- hydrologic maps
- topographic maps
- wetlands maps
- well data
- aerial photographic interpretation
- local conservation commission maps

Some examples of how the above information may be useful to the owner or operator in characterizing a release are given below:

- Knowledge of floodplain areas, surface water bodies, drainage patterns and flood control systems identifies potential migration pathways for surface and ground water contamination;
- Wind speed and direction may help identify air contaminant dispersion areas;
- Injection and withdrawal wells may provide locations and information (e.g., influences in ground-water flow patterns) for ground water monitoring;
- Structures on or offsite can provide ideal locations for subsurface gas monitoring; and
- Potential sources of contamination in close proximity to the facility may be revealed by investigating surrounding land use practices.

SURVEYING

Ground surveying is a direct process for obtaining topographic and other terrain features in the field. A local telephone directory should be consulted for companies providing surveying services.

Information that can be obtained from a ground survey includes:

- Facility boundary;
- Location of engineered structures (e.g., buildings, pipelines);
- Natural formations at the site (e.g., bedrock outcrops);
- Topographic features;
- Drainage patterns and ponding areas;
- Elevation benchmarks ("permanent" elevation reference points that can be used in the future);
- Location of ground water monitoring wells (e.g., surface location and elevation); and
- Profiles of surface water bodies (e.g., depths of lakes/ponds) that are not possible by aerial means.

The above information, obtained during a survey of the facility, may be useful in characterizing a contaminant release through:

- Identification of engineered structures that may inhibit or promote contaminant migration (e.g., accumulation areas for subsurface gas);
- Identification of natural features at the site (e.g., barriers or pathways) affecting contaminant migration;

- Topographic influences (e.g., drainage patterns and ponding areas);
- Location of ground water or subsurface gas monitoring wells;
- Ground-water depth (knowledge of location and elevation of wells, enables measurement of ground-water depth); and
- Depths of surface water bodies that may be useful in predicting surface water contamination and in determining ground-water breakout.

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APPENDIX B

MONITORING CONSTITUENTS AND INDICATOR PARAMETERS

LIST 1: Indicator Parameters Generally Applicable to Specific Media

LIST 2: Monitoring Constituents Potentially Applicable to Specific Media

LIST 3: Industry Specific Monitoring Constituents

LIST 1

INDICATOR PARAMETERS
GENERALLY APPLICABLE TO SPECIFIC MEDIA

SOIL

INDICATOR PARAMETERS

- Boron
- Calcium
- Chloride
- Copper
- Iron
- Magnesium
- Phosphorus
- Potassium
- Sodium
- Soil Eh
- Soil pH
- Sulfate
- Total Kjeldahl Nitrogen (TKN)
- Total Organic Carbon (TOC)
- Total Organic Halogen (TOX)
- Total Phenols
- Zinc

LIST 1 (Continued)

GROUND WATER

INDICATOR PARAMETERS

- Calcium
- Chloride
- Iron
- Magnesium
- Manganese
- pH
- Sodium
- Sulfate
- Specific Conductance
- Total Organic Carbon (TOC)
- Total Organic Halogen (TOX)
- Total Phenols

SUBSURFACE GAS

INDICATOR PARAMETERS

- Methane
- Carbon dioxide
- Total Hydrocarbons (THC)
- Colorimetric Indicators (e.g., Draeger Tubes)
- Explosivity

AIR

INDICATOR PARAMETERS

- Total Hydrocarbons (THC)
- Colorimetric Indicators (e.g., Draeger tubes)

LIST 1 (Continued)

SURFACE WATER

INDICATOR PARAMETERS

Alkalinity
Biochemical Oxygen Demand (BOD)
Calcium
Chemical Oxygen Demand (COD)
Chloride
Dissolved Oxygen (DO)
Magnesium
Nitrates
Nitrites
pH
Salinity
Sodium
Specific Conductance
Sulfate
Suspended solids
Temperature
Total solids
Total Organic Carbon (TOC)
Total Organic Halogen (TOX)
Total Phenols

List 2

MONITORING CONSTITUENTS POTENTIALLY APPLICABLE TO SPECIFIC MEDIA

Common Name	Chemical Abstracts No.	Ground Water	Surface Water2	Soil3	Subsurface Gas4	Air
Acetonitrile	75-05-8	X	X	X		X
Acetophenone	98-86-2	X	X	X		X
2-Acetylaminofluorene	53-96-3	X	X	X		
Acetyl chloride	75-36-5					
1-Acetyl-2-thiourea	591-08-2					
Acrolein	107-02-8	X	X	X		X
Acrylamide	79-06-1					X
Acrylonitrile	107-13-1	X	X	X		X
Aflatoxins	1402-68-2					
Aldicarb	116-06-3					X
Aldrin	309-00-2	X	X	X		
Allyl alcohol	107-18-6					
Allyl chloride	107-05-1	X	X	X		
Aluminum phosphide	20859-73-8					
4-Aminobiphenyl	92-67-1	X	X	X		
5-(Aminomethyl)-3-isoxazolol	2763-96-4					
4-Aminopyridine	504-24-5					
Amitrole	61-82-5					
Ammonium vanadate	7803-55-6					
Aniline	62-53-3	X	X	X		X
Antimony and compounds, N.O.S.[1]	7440-36-0	X	X	X		
Aramite	140-57-8	X	X	X		
Arsenic and compounds, N.O.S.[1]	7440-38-2	X	X	X		X
Arsenic acid	7778-39-4			X		
Arsenic pentoxide	1303-28-2			X		
Arsenic trioxide	1327-53-3			X		
Auramine	492-80-8					
Azaserine	115-02-6					
Barium and compounds, N.O.S.[1]	7440-39-3	X	X	X		
Barium cyanide	542-62-1			X		
Benz(c)acridine	225-51-4					

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Benz(a)anthracene	56-55-3	X	X	X		
Benzal chloride	98-87-3			X		
Benzene	71-43-2	X	X	X	X	X
Benzenearsonic acid	98-05-5					
Benzidine	92-87-5			X		
Benzo(b)fluoranthene	205-99-2	X	X	X		
Benzo(j)fluoranthene	205-82-3					
Benzo(a)pyrene	50-32-8	X	X	X		
p-Benzoquinone	106-51-4			X		
Benzotrichloride	98-07-7			X		X
Benzyl chloride	100-44-7			X		X
Beryllium and compounds, N.O.S.[1]	7440-41-7	X	X	X		
Bis(2-chloromethoxy)ethane	111-91-1	X	X	X		
Bis(2-chloroethyl) ether	111-44-4	X	X	X		
Bis(2-chloroisopropyl) ether	39638-32-9	X	X	X	X	
Bis(chloromethyl) ether	542-88-1			X		X
Bis(2-ethylhexyl)phthalate	117-81-7	X	X	X		X
Bromoacetone	589-31-2					
Bromoform	75-25-2	X	X	X		X
4-Bromophenyl phenyl ether	101-55-3	X	X	X		
Brucine	357-57-3					
Butyl benzyl phthalate	85-68-7	X	X	X		
Cacodylic acid	75-60-5					
Cadmium and compounds, N.O.S.[1]	7440-43-9	X	X	X		X
Calcium chromate	13765-19-0			X		
Calcium cyanide	592-01-8			X		
Carbon disulfide	75-15-0	X	X	X	X	X
Carbon oxyfluoride	353-50-4					X
Carbon tetrachloride	56-23-5	X	X	X	X	X
Chloral	75-87-6					

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Chlorambucil	305-03-3					
Chlordane, alpha and gamma isomers	57-74-9	X	X	X		X
Chlorinated benzenes, N.O.S.[1]		X	X	X	X	X
Chlorinated ethanes, N.O.S.[1]		X	X	X	X	X
Chlorinated fluorocarbons, N.O.S.[1]						X
Chlorinated naphthalene, N.O.S.[1]		X	X	X		
Chlorinated phenol, N.O.S.[1]				X		X
Chlornaphazine	494-03-1					
Chloroacetaldehyde	107-20-0					
Chloroalkyl ethers, N.O.S.[1]						
p-Chloroaniline	106-47-8	X	X	X		X
Chlorobenzene	108-90-7	X	X	X	X	X
Chlorobenzilate	510-15-6	X	X	X		
p-Chloro-m-cresol	59-50-7	X	X	X		
1-Chloro-2,3-epoxypropane	106-89-8					X
2-Chloroethyl vinyl ether	110-75-8			X		
Chloroform	67-66-3	X	X	X	X	X
Chloromethyl methyl ether	107-30-2					
beta-Chloronaphthalene	91-58-7	X	X	X		
o-Chlorophenol	95-57-8	X	X	X		X
1-(o-Chlorophenyl) thiourea	5344-82-1					
Chloroprene	126-99-8	X	X	X		X
3-Chloropropionitrile	542-76-7			X		
Chromium and compounds, N.O.S.[1]	7440-47-3	X	X	X		X
Chrysene	218-01-9	X	X	X		
Citrus red No. 2	6358-53-8					
Coal tars	8005-45-2			X		
Copper cyanide	544-92-3			X		X
Creosote	8001-58-9			X		
Cresols (Cresylic acid)	1319-77-3	X	X	X		X
Crotonaldehyde	4170-30-3					X

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Cyanides (soluble salts and complexes) N.O.S.[1]		X	X	X		X
Cyanogen	460-19-5					X
Cyanogen bromide	506-68-3					
Cyanogen chloride	506-77-4					
Cycasin	14901-08-7					
2-Cyclohexyl-4,6-dinitrophenol	131-89-5					
Cyclophosphamide	50-18-0					
2,4-D, salts and esters	94-75-7	X	X	X		X
Daunomycin	20830-81-3					
DDD	72-54-8	X	X	X		
DDE	72-55-9	X	X	X		
DDT	50-29-3	X	X	X		
Diallate	2303-16-4	X	X	X		
Dibenz(a,h)acridine	226-36-8					
Dibenz(a,j)acridine	224-42-0					
Dibenz(a,h)anthracene	53-70-3	X	X	X		
7H-Dibenzo(c,g)carbazole	194-59-2					
Dibenzo(a,e)pyrene	192-65-4			X		
Dibenzo(a,h)pyrene	189-64-0			X		
Dibenzo(a,i)pyrene	189-55-9			X		
1,2-Dibromo-3-chloropropane	96-12-8	X	X	X		
Dibutylphthalate	84-74-2	X	X	X		
o-Dichlorobenzene	95-50-1	X	X	X		X
m-Dichlorobenzene	541-73-1	X	X	X		X
p-Dichlorobenzene	106-46-7	X	X	X		X
Dichlorobenzene, N.O.S.[1]	25821-22-6	X	X	X		X
3,3'-Dichlorobenzidine	91-94-1	X	X	X		
1,4-Dichloro-2-butene	764-41-0	X	X	X		X
Dichlorodifluoromethane	75-71-8	X	X	X	X	X
1,2-Dichloroethylene	156-60-5	X	X	X	X	

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water^2	Soil^3	Subsurface Gas^4	Air
Dichloroethylene, N.O.S.[1]	25323-30-2	X	X	X		X
1,1-Dichloroethylene	75-35-4	X	X	X		X
2,4-Dichlorophenol	120-83-2	X	X	X		
2,6-Dichlorophenol	87-65-0	X	X	X		
Dichlorophenylarsine	696-28-6					
Dichloropropane, N.O.S.[1]	26638-19-7	X	X	X		X
Dichloropropanol, N.O.S.[1]	26545-73-3					
Dichloropropene, N.O.S.[1]	26952-23-8	X	X	X		X
1,3-Dichloropropene	542-75-6	X	X	X		X
Dieldrin	60-57-1	X	X	X		
1,2,3,4-Diepoxybutane	1464-53-5					
Diethylarsine	692-42-2					
1,4-Diethyleneoxide	123-91-1	X	X	X		X
N,N'-Diethylhydrazine	1615-80-1					
O,O-Diethyl S-methyldithiophosphate	3288-58-2					
Diethyl-p-nitro phenyl phosphate	311-45-5			X		
Diethylphthalate	84-66-2	X	X	X		X
0,0-Diethyl 0-pyrazinyl phosphorothioate	297-97-2	X	X	X		
Diethylstilbesterol	56-53-1					
Dihydrosafrole	94-58-6					
3,4-Dihydroxy-alpha-(methylamino)methyl benzyl alcohol	329-65-7					
Diisopropylfluorophosphate (DFP)	55-91-4					
Dimethoate	60-51-5	X	X	X		
3,3'-Dimethoxybenzidine	119-90-4	X	X	X		
p-Dimethoxyminoazobenzene	60-11-7	X	X	X		
7,12-Dimethylbenz(a)anthracene	57-97-6	X	X	X		
3,3'-Dimethylbenzidine	119-93-7	X	X	X		
Dimethylcarbamoyl chloride	79-44-7					
1,1-Dimethylhydrazine	57-14-7					X
1,2-Dimethylhydrazine	540-73-8					

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
alpha, alpha-Dimethylphenethylamine	122-09-8	X	X	X		
2,4-Dimethylphenol	105-67-9	X	X	X		X
Dimethylphthalate	131-11-3	X	X	X		
Dimethyl sulfate	77-78-1					
Dinitrobenzene, N.O.S.[1]	25154-54-5	X	X	X		
4,6-Dinitro-o-cresol and salts	534-52-1	X	X	X		
2,4-Dinitrophenol	51-28-5	X	X	X		
2,4-Dinitrotoluene	121-14-2	X	X	X		X
2,6-Dinitrotoluene	606-20-2	X	X	X		
Dinoseb	88-85-7	X	X	X		
Di-n-octylphthalate	117-84-0	X	X	X		
Diphenylamine	122-39-4	X	X	X		
1,2-Diphenylhydrazine	122-66-7			X		X
Di-n-propylnitrosamine	621-64-7	X	X	X		
Disulfoton	298-04-4	X	X	X		
Dithiobiuret	541-53-7					
Endosulfan	115-29-7	X	X	X		
Endothal	145-73-3					
Endrin	72-20-8	X	X	X		
Ethyl carbamate (urethane)	51-79-6					
Ethyl cyanide	107-12-0			X		
Ethylenebisdithiocarbamic acid, salts, and esters	111-54-6					
Ethylene dibromide	106-93-4					X
Ethylene dichloride	107-06-2				X	X
Ethylene glycol monoethyl ether	110-80-5					
Ethyleneimine	151-56-4					X
Ethylene oxide	75-21-8					X
Ethylenethiourea	96-45-7					
Ethylidene dichloride	75-34-3				X	X
Ethyl methacrylate	97-63-2	X	X	X		

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Ethylmethane sulfonate	62-50-0	X	X	X		
Famphur	52-85-7	X	X	X		
Fluoranthene	206-44-0	X	X	X		
Flourine	7782-41-4			X		
Fluoroacetamide	640-19-7					
Fluoroacetic acid, sodium salt	62-74-8					
Formaldehyde	50-00-0					X
Glycidylaldehyde	765-34-4					
Halomethane, N.O.S.[1]		X	X	X	X	X
Heptachlor	76-44-8	X	X	X		X
Heptachlor epoxide	1024-57-8	X	X	X		
Hexachlorobenzene	118-74-1	X	X	X		
Hexachlorobutadiene	87-68-3	X	X	X		X
Hexachlorocyclopentadiene	77-47-4	X	X	X		
Hexachlorodibenzo-p-dioxins		X	X	X		
Hexachlorodibenzofurans		X	X	X		
Hexachloroethane	67-72-1	X	X	X		X
Hexachlorophene	70-30-4	X	X	X		
Hexachloropropene	1888-71-7	X	X	X		
Hexaethyltetraphosphate	757-58-4					
Hydrazine	302-01-2					X
Hydrogen cyanide	74-90-8					X
Hydrogen fluoride	7664-39-3					
Hydrogen sulfide	7783-06-4			X	X	X
Indeno(1,2,3cd)pyrene	193-39-5	X	X	X		
Iron dextran	9004-66-4					
Isobutyl alcohol	78-83-1	X	X	X		X
Isodrin	465-73-6	X	X	X		
Isosafrole	120-58-1	X	X	X		
Kepone	143-50-0	X	X	X		
Lasiocarpine	303-34-4					
Lead and compounds, N.O.S.[1]	7439-92-1	X	X	X		X
Lead acetate	301-04-2			X		

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Lead phosphate	7446-27-7			X		
Lead subacetate	1335-32-6					
Lindane	58-89-9	X	X	X		
Maleic anhydride	108-31-6					X
Maleic hydrazide	123-33-1					
Malonitrile	109-77-3			X		
Melphalan	148-82-3					
Mercury fulminate	628-86-4					
Mercury and compounds N.O.S.[1]	7439-97-6	X	X	X		X
Methacrylonitrile	126-98-7	X	X	X		X
Methapyrilene	91-80-5	X	X	X		
Methomyl	16752-77-5					
Methoxychlor	72-43-5	X	X	X		
Methyl bromide	74-83-9	X	X	X		X
Methyl chloride	74-87-3	X	X	X		X
Methychlorocarbonate	79-22-1					
Methyl chloroform	71-55-6	X	X	X	X	X
3-Methylcholanthrene	56-49-5	X	X	X		
4,4',Methylenebis(2-chloroaniline)	101-14-4	X	X	X		
Methylene bromide	74-95-3	X	X	X		
Methylene chloride	75-09-2	X	X	X	X	X
Methyl ethyl ketone (MEK)	78-93-3	X	X	X		X
Methyl ethyl ketone peroxide	1338-23-4			X		X
Methyl hydrazine	60-34-4					
Methyl iodide	74-88-4	X	X	X		X
Methyl isocyanate	624-83-9					X
2-Methyllactonitrile	75-86-5					X
Methyl methacrylate	80-62-6	X	X	X		X
Methyl methanesulfonate	66-27-3	X	X	X		
Methyl parathion	298-00-0	X	X	X		

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Methylthiouracil	56-04-2					
Mitomycin C	50-07-7					
MNNG	70-25-7					
Mustard gas	505-60-2					
Naphthalene	91-20-3	X	X	X		X
1,4-Naphthoquinone	130-15-4	X	X	X		
alpha-Naphthylamine	134-32-7	X	X	X		
Beta-Naphthylamine	91-59-8	X	X	X		
alpha-Napththylthiourea	86-88-4					
Nickel and compounds, N.O.S.[1]	7440-02-0	X	X	X		X
Nickel carbonyl	13463-39-3					
Nickel cyanide	557-19-7			X		
Nicotine and salts	54-11-5					
Nitric oxide	10102-43-9			X		X
p-Nitroaniline	100-01-6	X	X	X		
Nitrobenzene	98-95-3	X	X	X		X
Nitrogen dioxide	10102-44-0			X		
Nitrogen mustard and hydrochloride salt	51-75-2			X		
Nitrogen mustard N-oxide and hydrochloride salt	126-85-2					
Nitroglycerin	55-63-0					X
p-Nitrophenol	100-02-7	X	X	X		X
2-Nitropropane	79-46-9					
4-Nitroquinoline-1-oxide	56-57-5	X	X	X		
Nitrosamine, N.O.S.[1]	35576-91-1	X	X	X		
N-Nitrosodi-n-butylamine	924-16-3	X	X	X		
N-Nitrosodiethanolamine	1116-54-7					
N-Nitrosodiethylamine	55-18-5	X	X	X		
N-Nitrosodimethylamine	62-75-9	X	X	X		
N-Niroso-N-ethyl urea	759-73-9					
N-Nitrosomethylethylamine	10595-95-6	X	X	X		
N-Nitroso-N-methylurea	684-93-5					

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
N-Nitroso-N-methylurethane	615-53-2					
N-Nitrosomethylvinylamine	4549-40-0					
N-Nitrosomorpholine	59-89-2	X	X	X		
N-Nitrosonornicotine	16543-55-8					
N-Nitrosopiperidine	100-75-4	X	X	X		
Nitrosopyrolidine	930-55-2	X	X	X		
N-Nitrososarcosine	13256-22-9					
5-Nitro-o-toluidine	99-55-8	X	X	X		
Octamethylpryophosphoramide	152-16-9					
Osmium tetroxide	20816-12-0					X
Paraldehyde	123-63-7					
Parathion	56-38-2	X	X	X		X
Pentachlorobenzene	608-93-5	X	X	X		X
Pentachlorodibenzo p dioxins		X	X	X		
Pentachlorodibenzofurans		X	X	X		
Pentachloroethane	76-01-7	X	X	X		X
Pentachloronitrobenzene (PCNB)	82-68-8	X	X	X		
Pentachlorophenol	87-86-5	X	X	X		X
Phenacetin	62-44-2	X	X	X		
Phenol	108-95-2	X	X	X		X
Phenylenediamine	25265-76-3					
Phenylmercury acetate	62-38-4					
Phenylthiourea	103-85-5					
Phosgene	75-44-5					X
Phosphine	7803-51-2					X
Phorate	298-02-2	X	X	X		X
Phthalic acid esters, N.O.S.[1]						
Phthalic anhydride	85-44-9					X
2-Picoline	109-06-8	X	X	X		
Polychlorinated biphenyls N.O.S.[1]		X	X	X		X
Potassium cyanide	151-50-8			X		
Potassium silver cyanide	506-61-6			X		
Pronamide	23950-58-5	X	X	X		

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
1,3-Propane sultone	1120-71-4					
n-Propylamine	107-10-8					
Propargyl alcohol	107-19-7					
Propylene dichloride	78-87-5					X
1,2-Propylenimine	75-55-8					
Propylthiouracil	51-52-5					
Pyridine	110-86-1	X	X	X		X
Reserpine	50-55-5					X
Resorcinol	108-46-3			X		X
Saccharin and salts	81-07-2					
Safrole	94-59-7	X	X	X		
Selenium dioxide	7783-00-8					
Selenium and compounds, N.O.S.	7782-49-2	X	X	X		
lenium sulfide	7446-34-6			X		
elenourea	630-10-4					
Silver and compounds, N.O.S.[1]	7440-22-4	X	X	X		
Silver cyanide	506-64-9			X		
Silvex (2,4,5-TP)	93-72-1	X	X	X		
Sodium cyanide	143-33-9					
Streptozotocin	18883-66-4					
Strontium sulfide	1314-96-1			X		
Strychnine and salts	57-24-9					
TCDD	1746-01-6	X	X	X		X
1,2,4,5-Tetrachlorobenzene	95-94-3	X	X	X		
Tetrachlorodibenzo-p-dioxins		X	X	X		
Tetrachlorodibenzofurans		X	X	X		
Tetrachloroethane, N.O.S.[1]	25322-20-7	X	X	X	X	
1,1,1,2-Tetrachloroethane	630-20-6	X	X	X		
1,1,2,2-Tetrachloroethane	79-34-5	X	X	X	X	
Tetrachloroethylene	127-18-4	X	X	X	X	X

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
2,3,4,6-Tetrachlorophenol	58-90-2	X	X	X		
Tetraethyldithiopyrophosphate	3689-24-5	X	X	X		
Tetraethyl lead	78-00-2					X
Tetraethylpyrophosphate	107-49-3			X		
Tetranitromethane	509-14-8			X		
Thallium and compounds, N.O.S.[1]	7440-28-0	X	X	X		
Thallic oxide	1314-32-5			X		
Thallium (1) acetate	563-68-8			X		
Thallium (1) carbonate	6533-73-9			X		
Thallium (1) chloride	7791-12-0			X		
Thallium (1) nitrate	10102-45-1			X		
Thallium selenite	12039-52-0			X		
Thallium (1) sulfate	10031-59-1			X		
Thioacetamide	62-55-5					X
Thiofanox	39196-18-4					
Thiomethanol	74-93-1					X
Thiophenol	108-98-5			X		
Thiosemicarbazide	79-19-6					
Thiourea	62-56-6					
Thiram	137-26-8					
Toluene	108-88-3	X	X	X	X	X
Toluenediamine	25376-45-8					
2,4-Toluenediamine	95-80-7					X
2,6-Toluenediamine	823-40-5					
3,4-Toluenediamine	496-72-0					
Toluene diisocyanate	584-84-9			X		X
p-Toluidine	106-49-0					
o-Toluidine hydrochloride	636-21-5					
Toxaphene	8001-35-2	X	X	X		X
1,2,4-Trichlorobenzene	120-82-1	X	X	X		X
1,1,2-Trichloroethane	79-00-5	X	X	X	X	

List 2 (continued)

Common Name	Chemical Abstracts No.	Ground Water	Surface Water[2]	Soil[3]	Subsurface Gas[4]	Air
Trichloroethylene	79-01-6	X	X	X	X	X
Trichloromethanethiol	75-70-7			X		
Trichloromonofluoromethane	75-69-4	X	X	X		
2,4,5-Trichlorophenol	95-95-4	X	X	X		
2,4,6-Trichlorophenol	88-06-2	X	X	X		
2,4,5-T	93-76-5	X	X	X		
Trichloropropane, N.O.S.[1]		X	X	X		X
1,2,3-Trichloropropane	96-18-4	X	X	X		X
0,0,0-Triethylphosphorothioate	126-68-1	X	X	X		
sym-Trinitrobenzene	99-35-4	X	X	X		
Tris(1-aziridinyl)phosphine sulfide	52-24-4					
Tris(2,3-dibromopropyl)phosphate	126-72-7					
Trypan blue	72-57-1					
Uracil mustard	66-75-1					
Vanadium pentoxide	1314-62-1			X		X
Vinyl chloride	75-01-4	X	X	X	X	X
Warfarin	81-81-2					
Zinc cyanide	557-21-1			X		
Zinc phosphide	1314-84-7			X		

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[1] The abbreviation N.O.S. (not otherwise specified) signifies those members of the general class not specifically listed by name.

[2] Applies to the water column only. Additional constituents may be of concern if sediment and/or biota are to be sampled and subjected to analysis (See Section 13).

[3] Includes both saturated and unsaturated soils. Some of these are gases at ambient temperature and pressure which may be present in wet or saturated soils. Degradation as a result of chemical, biological or physical processes, may result in decreasing concentrations of constituents over time, and is dependent on moisture content as well as other factors.

[4] Compounds indicated are those which may be present within a carrier gas (e.g., methane).

LIST 3

INDUSTRY SPECIFIC MONITORING CONSTITUENTS

REFERENCES FOR INDUSTRY SPECIFIC MONITORING CONSTITUENTS

1. 40 CFR 122, National Pollutant Discharge Elimination System
2. U.S. EPA, Development Document for Effluent Limitation Guidelines and Standards fo the ... Point Source Category.
   (Total of 30 Industries)
3. U.S. EPA, 1980, Treatability Manual. Volume I. Treatability Data
4. U.S. EPA Regional Offices for Industry Specific Data.

LIST 3*

SW-846 Chemical Classifications - See Supplemental Tables

Industrial Category	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2-10	2-11	2-12	2-13	2-14	2-15
Auto and Other Laundries	●	●	●	●		●		●		●		●		●	●
Coal Mining	●	●	●	●		●		●		●		●		●	●
Coal Coating	●	●		●		●		●		●		●		●	●
Copper Forming	●		●	●		●				●		●		●	●
Electroplating	●					●				●				●	●
Electrical and Electronic Components	●	●	●	●		●		●		●		●		●	●
Explosives Manufacturing	●	●	●			●				●		●		●	●
Foundries	●	●	●	●		●		●		●		●		●	●
Gum and Wood Chemicals	●					●		●		●		●		●	●
Inorganic Chemicals Manufacturing	●	●	●	●		●				●		●	●	●	●
Iron and Steel Manufacturing	●	●	●	●	●	●		●		●		●	●	●	●
Leather Tanning and Finishing	●	●		●		●				●		●		●	●
Metal Finishing	●	●	●	●	●	●		●		●		●	●	●	●
Nonferrous Metals Manufacturing	●	●	●	●		●		●		●		●		●	●
Ore Mining	●	●				●		●		●		●		●	●
Organic Chemicals Manufacturing	●	●	●	●		●		●		●		●		●	●
Paint and Ink Formulation	●	●	●			●		●		●		●		●	●
Pesticides and Herbicides	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

LIST 3 (Continued)*

SW-846 Chemical Classifications - See Supplemental Tables

Industrial Category	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2-10	2-11	2-12	2-13	2-14	2-15
Petroleum Refining	●	●		●		●		●		●		●		●	●
Pharmaceutical Preparations	●	●	●	●		●		●		●		●	●	●	●
Photographic Equipment and Supplies	●	●	●	●		●				●		●		●	●
Plastics Molding and Forming	●	●		●		●		●		●		●		●	●
Porcelain Enameling	●	●				●				●		●		●	●
Pulp and Paper Mills	●	●	●	●		●		●		●		●	●	●	●
Rubber Processing	●	●	●			●				●		●	●	●	●
Soap and Detergent Manufacturing	●	●		●		●		●		●		●		●	●
Steam Electric Power Plants	●	●	●	●		●		●		●		●	●	●	●
Textile Mills	●	●	●	●	●	●		●		●		●	●	●	●
Timber Products	●			●		●		●		●		●		●	●
Wood Preserving	●	●	●	●		●		●		●		●	●	●	●

* - A "●" indicates that one or more constituents within a category are likely candidates for monitoring.

- This list does not contain all industries that may be subject to an RFI.

- The constituents within the categories indicated may not be mutually exclusive. If a chemical category is checked for a particular industry, the owner or operator is responsible for all constituents within the category, regardless of whether the constituent is contained in other categories.

SUPPLEMENT TO LIST 3

REPRINTED TABLES FROM "TEST METHODS FOR EVALUATING SOLID WASTES: 3RD ED. U.S. EPA SW-846. GPO No. 955-001-0000-1. 1986.

Table 2-1: Phenols and Organic Acids

Benzoic acid
Benzyl alcohol
2-sec-Butyl-4,6-dinitrophenol (DNBP)
4-Chloro-3-methylphenol
2-Chlorophenol
Cresol (methyl phenols)
2-Cyclohexyl-4,6-dinitrophenol
2,4-Dichlorophenol
2,6-Dichlorophenol
2,4-Dimethylphenol
4,6-Dinitro-o-cresol
2,4-Dinitrophenol
2-Methyl-4,6-dinitrophenol
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
Tetrachlorophenols
Trichlorophenols

Table 2-2: Phthalate Esters

Benzyl butyl phthalate
Bis(2-ethylhexyl)phthalate
Diethyl phthalate
Di-n-butyl phthalate
Dimethyl phthalate
Di-n-octyl phthalate

Table 2-3: Nitroaromatics and Cyclic Ketones

Dinitrobenzene
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Isophorone
Naphthoquinone
Nitrobenzene

Table 2-4: Polyaromatic Hydrocarbons

Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(j)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Chrysene
Dibenz(a,h)acridine
Dibenz(a,j)acridine
Dibenz(a,h)anthracene (Dibenzo(a,h)anthracene)
7H-Dibenzo(c,g)carbazole
Dibenzo(a,e)pyrene
Dibenzo(a,h)pyrene
Dibenzo(a,i)pyrene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
3-Methylcholanthrene
Naphthalene
Phenanthrene
Pyrene

Table 2-5: Chlorinated Hydrocarbons

Benzotrichloride
Benzyl chloride
2-Chloronaphthalene
Dichlorobenzenes
Dichloromethylbenzenes (Dichlorotoluenes)
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclohexane
Hexachlorocyclopentadiene
Hexachloroethane
Pentachlorohexane
Tetrachlorobenzenes
Trichlorobenzenes

Table 2-6: Base/Neutral

Acenaphthene
Acenaphthylene
Acetophenone
Aldrin
Aniline
Anthracene
4-Aminobiphenyl
Aroclor-1016
Aroclor-1221
Aroclor-1232
Aroclor-1242
Aroclor-1248
Aroclor-1254
Aroclor-1260
Benzidine
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Benzo(a)pyrene
α-BHC
β-BHC
δ-BHC
γ-BHC
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
4-Bromophenyl phenyl ether
Butyl benzyl phthalate
Chlordane
4-Chloroaniline
1-Chloronaphthalene
2-Chloronaphthalene
4-Chlorophenyl phenyl ether
Chrysene
4,4'-DDD
4,4'-DDE
4,4'-DDT
Dibenz(a,j)acridine
Dibenz(a,h)anthracene
Dibenzofuran
Di-n-butyl phthalate
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,2-Dichlorobenzene
3,3'-Dichlorobenzidine
Dieldrin
Diethyl phthalate
p-Dimethylaminoazobenzene
7,12-Dimethylbenz(a)anthracene
α-,α-Dimethylphethylamine
Dimethyl phthalate
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diphenylamine
1,2-Diphenylhydrazine
Di-n-octyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin aldehyde
Endrin ketone
Ethyl methanesulfonate
Fluoranthene
Fluorene
2-Fluorobiphenyl
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
3-Methylcholanthrene
Methyl methanesulfonate
2-Methylnaphthalene
Naphthalene
1-Naphthylamine
2-Naphthylamine
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
Nitrobenzene
N-Nitroso-di-n-butylamine
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodipropylamine
N-Nitrosopiperidine
Pentachlorobenzene
Pentachloronitrobenzene
Phenacetin
Phenanthrene
2-Picoline
Pronamide
Pyrene
1,2,4,5-Tetrachlorobenzene
1,2,4-Trichlorobenzene
Toxaphene

Table 2-7: Organophosphorous Pesticides

Azinphos methyl
Bolstar (Sulprofos)
Chlorpyrifos
Coumaphos
Demeton
Diazinon
Dichlorvos
Dimethoate
Disulfoton
EPN
Ethoprop
Fensulfothion
Fenthion
Malathion
Merphos
Mevinphos
Monochrotophos
Naled
Parathion
Parathion methyl
Phorate
Ronnel
Stirophos (Tetrachlorvinphos)
Sulfotepp
TEPP
Tokuthion (Prothiofos)
Trichloronate

Table 2-8: Organochlorine Pesticides and PCB's

Aldrin
α-BHC
β-BHC
δ-BHC
γ-BHC (Lindane)
Chlordane
4,4'-DDD
4,4'-DDE
4,4'-DDT
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide
Kepone
Methoxychlor
Toxaphene
PCB-1016 (Aroclor-1016)
PCB-1221 (Aroclor-1221)
PCB-1232 (Aroclor-1232)
PCB-1242 (Aroclor-1242)
PCB-1248 (Aroclor-1248)
PCB-1254 (Aroclor-1254)
PCB-1260 (Aroclor-1260)

Table 2-9: Chlorinated Herbicides

2,4-D
2,4-DB
2,4,5-T
2,4,5-TP (Silvex)
Dalapon
Dicamba
Dichloroprop
Dinoseb
MCPA
MCPP

Table 2-10: Halogenated Volatiles

Benzyl chloride
Bis(2-chloroethoxy)methane
Bis(2-chloroisopropyl)ether
Bromobenzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon tetrachloride
Chloracetaldehyde
Chloral
Chlorobenzene
Chloroethane
Chloroform
1-Chlorohexane
2-Chloroethyl vinyl ether
Chloromethane
Chloromethyl methyl ether
Chlorotoluene
Dibromochloromethane
Dibromomethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene (Vinylidene chloride)
trans-1,2-Dichloroethylene
Dichloromethane
1,2-Dichloropropane
1,3-Dichloropropylene
1,1,2,2-Tetrachloroethane
1,1,1,2-Tetrachloroethane
Tetrachloroethylene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
Trichloropropane
Vinyl chloride

Table 2-11: Non-halogenated Volatiles

Acrylamide
Diethyl ether
Ethanol
Methyl ethyl ketone (MEK)
Methyl isobutyl ketone (MIBK)
Paraldehyde (trimer of acetaldehyde)

Table 2-12: Aromatic Volatiles

- Benzene
- Chlorobenzene
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Ethyl benzene
- Toluene
- Xylenes (Dimethyl benzenes)

Table 2-13: Acetonitrile, Acrolein, Acrylonitrile

- Acetonitrile
- Acrolein (Propenal)
- Acrylonitrile

Table 2-14: Volatiles

Acetone
Acrolein
Acrylonitrile
Benzene
Bromochloromethane
Bromodichloromethane
4-Bromofluorobenzene
Bromoform
Bromomethane
2-Butanone (Methyl ethyl ketone)
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-Chloroethyl vinyl ether
loroform
Chloromethane
Dibromomethane
1,4-Dichloro-2-butane
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichlrorethene
trans-1,2-Dichloroethene
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
1,4-Difluorobenzene
Ethanol
Ethylbenzene
Ethyl methacrylate
2-Hexanone
Iodomethane
Methylene chloride
4-Methly-2-pentanone
Styrene
1,1,2,2-Tetrachloroethane
Toluene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Trichlorofluoromethane
1,2,3-Trichloropropane
Vinyl acetate
Vinyl chloride
Xylene